Sample Designs for Avian Monitoring Alternatives in Sierra Nevada Network Parks

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1) Introduction

This document outlines the rationale, goals, sampling design, and methods proposed for each of two spatially extensive landbird monitoring programs in the Sierra Nevada Network (SIEN), which comprises Yosemite National Park (YOSE), Sequoia and Kings Canyon National Park (SEKI--treated as a single entity throughout this document, although technically speaking comprises two distinct parks), and Devil's Postpile National Monument (DEPO). The contents reflect preliminary decisions made by SIEN personnel at a planning meeting in October 2004. Prior to that meeting, representatives from the SIEN and IBP developed a list of potential focal areas for landbird monitoring in the network that included 'landscape-level' population trends as well as population trends and/or other population parameters for numerous specific habitats of interest: montane meadows, foothill oak woodland and chaparral, montane riparian areas, montane oak woodland, and high-elevation areas (including both subalpine and alpine habitats). After considering each possibility, we pared the list down to four alternatives:

1) monitor 'landscape level' avian population trends,
2) monitor avian population trends in montane meadows,
3) monitor avian population trends in high-elevation (subalpine and alpine) habitats, or
4) monitor avian population trends in low-elevation (foothill) habitats.

At the October 2004 meeting we discussed all four alternatives and recommended alternatives #1 and #2 for further development into more detailed landbird monitoring proposals that could be integrated into the Network's long-term ecological monitoring program. This report is intended to develop more fully the two alternative monitoring programs. Ideally either of these programs would complement rather than replace the landbird demographic data currently being gathered at MAPS (Monitoring Avian Productivity and Survivorship) stations throughout the parks, but the assessment of existing MAPS stations is outside the purview of this report, and indeed, has recently been completed in a separate report (DeSante et al. 2005).

In **Chapter 2** we describe the 'landscape-level' monitoring program, structuring our presentation according to the guidelines for a 'protocol narrative' for long-term monitoring projects developed by Oakley et al. (2003). Finer methodological details will need to be developed later as part of a set of standard operating procedures (SOP's) should the alternative be adopted.

In **Chapter 3** we provide a preliminary assessment of the landscape-level monitoring program's statistical power to detect population trends, based largely on data from our landbird inventory at SEKI (Siegel and Wilkerson 2004b; Siegel and Wilkerson *in preparation*).

In **Chapter 4** we compile data from our recent efforts to classify habitat at Breeding Bird Survey stop locations throughout the Sierra Nevada, and use the results to assess which Sierra habitats are under-sampled by existing bird monitoring efforts in the Sierra. We suggest this assessment may inform SIEN decisions if the network chooses to focus landbird monitoring efforts on one or more specific habitats, rather than implementing the landscape-level monitoring program.

In **Chapter 5** we describe the monitoring program for meadow-associated bird species, again structuring our presentation according to the outline and suggestions for a ‘protocol narrative’ for long-term monitoring projects provided by Oakley et al. (2003).

2) Landbird Monitoring Alternative A:
'Landscape-level' Monitoring of Landbird Population Trends

2.1) Background and objectives

a) Background and history

Reported declines of many bird species breeding in North America have stimulated interest in avian population trends and mechanisms driving those trends (Robbins et al. 1989; DeSante and George 1994; Peterjohn et al. 1995). Data from the North American Breeding Bird Survey indicate that many landbird populations in the Sierra Nevada are declining (Siegel and DeSante 1999; Sauer and Hines 2004).

Graber (1996) and DeSante (1995) identified eight potential Sierra-wide risks faced by Sierra landbirds: livestock grazing, logging, fire suppression, exurban development, increased recreational use, pesticide use (both in the Sierra and upwind in the Central Valley), habitat destruction and degradation on the wintering grounds, and large-scale climate change. Although many of these risks would not appear to play a large role in the national parks, data from the Monitoring Avian Productivity and Survivorship (MAPS) program suggest that populations of numerous species are declining in Yosemite, and that the majority of those declines appear to be tied primarily to low productivity (presumably resulting from factors occurring *in the park*), rather than low survival (DeSante et al. 2004, 2005).

The three units in the SIEN--Yosemite National Park, Sequoia and Kings Canyon National Park, and Devil's Postpile National Monument--collectively range in elevation from 400 m in the Sierra foothills to 4,418 m at the top of Mt. Whitney, and contain huge tracts of mid-elevation and subalpine conifer forest, as well as substantial acreage of chaparral, oak woodland and savanna, upland hardwood forest, meadows, and alpine plant communities. The goal of 'landscape-level' monitoring is to assess park-wide and Network-wide landbird population trends by monitoring population densities across the parks' diverse habitats and broad habitat gradients.

National Parks in the SIEN can fulfill vital roles as both refuges for bird species dependent on late successional forest conditions, and as reference sites for assessing the effects of land use and land cover changes on bird populations throughout the Sierra Nevada region (Silsbee and Peterson 1991). These changes may result from regional activities such as land conversion and forest management, or from broader-scale processes such as global climate change. Indeed, monitoring population trends at 'control' sites in national parks is especially important because the parks are among the few sites in the United States where population trends due to large-scale regional or global change patterns are not confounded with local changes in land-use (Simons et al. 1999). Additionally, long-term monitoring of landbirds throughout the Network is expected to provide information that will inform future decisions about important management issues *in the parks*, including visitor impacts, fire management, and the effects of introduced species.

b) Rationale for selecting this resource to monitor

Landbird populations provide an excellent resource to monitor for several reasons. First, landbird monitoring is particularly efficient, in the sense that many species can be monitored simultaneously with the same survey protocol, and costs are relatively low. Preliminary analyses suggest that our project design will allow monitoring of population trends, with a reasonable degree of statistical power, for dozens of species (see Chapter 3 of this report). This capacity to capture a fairly broad sector of park resources (i.e. numerous bird species) elevates the desirability of monitoring landbirds over some other taxa, for which expensive projects may only monitor a single species (Croze 1982; Manley et al. 2004). Relative to other animal taxa, landbirds are easy to detect during the breeding season, and can even be surveyed with just a single annual site visit (Siegel et al. 2001). They generally occupy a high position on the food web and they provide important ecological functions such as seed dispersal and insect control, making them good indicators of changes in ecosystems (Furness et al. 1993; Greenwood et al. 1993).

Well-developed, standardized data collection and analytical procedures for estimating landbird population density already exist, and will facilitate comparisons between SIEN results and data from other regional and national efforts. The existence of other regional and national landbird monitoring efforts, such as the Breeding Bird Survey (Droege 1990; Peterjohn and Sauer 1993) does not, however, suggest that monitoring efforts in the SIEN are unnecessary or redundant. Sierra Nevada BBS routes provide relatively good coverage of mid-elevation conifer forest habitats, but include far fewer points in more geographically limited mid-elevation habitats such as montane meadow and montane chaparral, and fewer still in the foothill, subalpine and alpine zones (see Chapter 4 of this report). Even within mid-elevation forests, late-successional conditions are generally poorly sampled by the BBS and other regional bird monitoring activities, but are well represented in the SIEN parks. Additionally, although the BBS has been very valuable in documenting geographically broad population changes, BBS data are collected exclusively at roadsides and are thus of limited value for extending inferences to areas not adjacent to roads (O'Connor 1992; DeSante and George 1994; Sauer 2000), and the resolution of trends is generally too coarse for regional (let alone park-level) decision-making (Sauer and Cooper 2000; Hutto and Young 2002).

Substantial knowledge about habitat relationships and bird community structure in the Sierra Nevada (e.g. Beedy and Granholm 1985; Gaines 1992; Siegel and DeSante 1999), as well as more specific information about the current status of landbirds in the SIEN, already exists and has informed this project design. MAPS (Monitoring Avian Productivity and Survivorship) stations have collected demographic data at multiple meadow and riparian sites throughout all three SIEN parks (Gates and Heath 2003; DeSante et al. 2005) since the first station was established at Yosemite's Hodgdon Meadow in 1990. Spatially extensive landbird inventories, utilizing off-trail point counts, have been completed at Yosemite National Park (Siegel and DeSante 2002) and Devil's Postpile National Monument (Siegel and Wilkerson 2004a), and nearly completed at Sequoia and King's Canyon National Park (Siegel and Wilkerson 2004b; Siegel and Wilkerson *in preparation*). These inventory efforts provided opportunities to test and streamline field methodologies and analytical approaches, and produced datasets that helped to assess the statistical power of the proposed monitoring program (see Chapter 3 of this report).

Finally, landbirds hold high and growing public interest (Cordell et al.1999; Cordell and Herbert 2002) and are perhaps the most visible faunal component of park ecosystems. Monitoring data and results will likely be of great interest to a substantial subset of park visitors, and could provide the raw material for excellent public education efforts.

c) Measurable objectives

The primary objective of this monitoring project is to determine trends in the abundance of as many landbird species (including passerines, near-passerines, and galliformes) as possible throughout accessible areas of the SIEN parks during the breeding season. For commonly detected species, we will be able to achieve park-level inference, allowing comparisons between trends at the different parks. A shared methodology between all three parks across the SIEN will ensure Network consistency and allow us to avoid the pitfalls that can make comparisons between parks difficult or misleading (Quinn and van Riper 1990; Sauvajot et al. 1990; Silsbee and Peterson 1991). For some rarer species and habitat specialists that occur only in subalpine, riparian, or other limited or difficult to sample habitats, making inferences on population trends may not be possible at the geographic scale of the individual park, but will be possible at the Network-wide scale when we aggregate data from multiple parks.

A secondary objective of the project is to track changes in the distribution of landbird species throughout the parks during the breeding season. This objective provides an additional metric for assessing changes in bird communities throughout the Network, as some important ecological changes, such as populations moving upslope in response to climate change, may not necessarily be discernible by simply looking at aggregate population trends.

2.2) Sampling design

a) Rationale for selecting this sampling design over others

In concordance with other NPS bird monitoring protocols that have been developed recently or are currently under development (Coonan et al. 2001; Peitz et al. 2002; Siegel et al. 2005), this protocol surveys landbirds with 5-minute, variable circular plot (VCP) point counts (Reynolds et al. 1980; Fancy 1997; Nelson and Fancy 1999; Buckland et al. 2001; Rosenstock et al. 2002). VCP point counts rely upon distance sampling (Buckland et al. 2001), which facilitates the estimation of detection probability--a parameter that may vary greatly by species, habitat, observer, or other factors. Estimates of detection probability permit the estimation of absolute density of birds across the landscape, a much more meaningful metric than the relative abundance indices that can be produced from point counts that do not incorporate distance sampling.

Other features of this protocol are intended to address the challenges inherent in working in vast, rugged parks with large roadless areas. These challenges include:

1) *safety concerns*. Substantial portions of both large parks are rendered essentially inaccessible by prohibitively steep slopes or dangerous river crossings.

2) *high travel costs*. Substantial portions of the large parks are not only many kilometers away from the nearest road, they are also many kilometers away from the nearest trail. There are places in the more remote parts of both large parks that could require up to a week simply to reach. Given the tight financial constraints likely to impact this project, attempting to reach such remote places would consume an inordinate proportion of available resources, and would greatly reduce the number of points that could be surveyed each year.

3) *diverse habitats*. Both large parks span enormous elevational gradients, producing substantial intra-park variation in avian community composition, breeding phenology, and average date of accessibility by crew members.

To address the first two issues, we have restricted our sampling frame to accessible areas of the parks within 1.625 km of a road or trail. Transects will 'start' from points on trails, and run perpendicularly away form the trails for up to 1.625 km in both directions (we explain the rationale for using 1.625 km in Section 2d, below). We are defining the more remote portions of the parks (areas farther than 1.625 km from a road or trail) as a separate stratum, which, under likely funding and staffing constraints, will not be sampled at all. We considered sampling this 'remote' stratum as part of the proposed program, with effort stratified in a manner that would ensure that most of our sampling would still occur in the 'accessible' stratum. Unfortunately, with just a two-person crew working in each park, there is no minimal amount of effort that could be channeled into the remote stratum without siphoning substantial resources away from sampling in the 'accessible' stratum. If, for example, the crew spent one of their six weeklong tours each year working in the remote stratum, this might yield just a single transect, as traveling to and from the starting point would consume the rest of the week. In some cases it might not even be possible to reach the starting point and return in just seven days. Even under a better scenario, a full week (six transects) in the 'accessible' stratum would need to be sacrificed for just a single day of surveying in the 'remote' transect. Perhaps even more importantly, given the heterogeneity of habitat conditions (including elevation, aspect, weather, and plant community) covered by the 'remote' stratum in each large park, a single transect each year could not adequately 'represent' the remote stratum, and would likely yield spurious results. Thus, under current budgetary and logistic constraints, sampling the 'remote' stratum would appear to incur excessive opportunity costs (in terms of sacrificed sample size from the 'accessible' stratum') and safety risks, for little if any real benefit. In the future, should existing financial and staffing constraints be relaxed, the survey could potentially be augmented with transects in the 'remote' stratum.

To address the third issue, we have selected an 'augmented, serially alternating' panel design (Urquhart et al. 1998; Siegel et al. 2005), wherein approximately half of the annual survey effort will be devoted to surveying transects that are revisited annually, while the remaining survey effort will be devoted to one of four panels of additional transects that will be sampled every four years. A panel design with effort split approximately evenly between annually revisited transects and transects in the four-year serially alternating panels allows a much larger number of transects (and regions of the parks) to be included in the sampling scheme than if each transect were to be revisited annually, but still allows for a reasonable amount of year-to-year continuity (Breidt and Fuller 1999; Urquhart and Kincaid 1999; McDonald 2003).

b) Site selection

i) Criteria for site selection; define the boundaries of the population being sampled Sampling will take place during the breeding season only (mid May through the third week of July). Crew members in each park will survey the lowest elevation transects at the beginning of the field season, and then work their way upslope gradually as the season progresses. This will ensure that all transects are surveyed near the peak of the breeding season for the elevation zone they represent. All bird species will be recorded on surveys, but species targeted for trend analysis will include all terrestrial bird species that are considered reasonably well-sampled by point counts-- passerines, near-passerines, and galliformes.

ii) Procedures for selecting sampling locations; stratification, spatial design

For each large park, we designated a potential transect starting point every 50 m along all trail segments. We used GIS data to establish the elevation of each of these potential starting points, and then classified the points as belonging to low-, mid- or high-elevation strata. We defined the low-elevation stratum as all the potential starting points that were less than 1,350 m above sea level; the mid-elevation stratum encompassed points between 1,350 m and 2,750 m above sea level, and the high-elevation stratum comprised points above 2,750 m. We then selected our sample in each park from the candidate points, using PSURVEY.DESIGN, an environmental monitoring design package that is available from T. Olsen (U.S. EPA, Western Ecology Division, Corvallis) and which runs in conjunction with the statistical software R (R Development Core Team 2004). The software draws a sample from a spatially explicit set of candidate points using the Generalized Random-Tessellation Stratified (GRTS) sampling method with reverse hierarchical ordering (Stevens and Olsen 1999, 2003, 2004). GRTS sampling methods are increasingly being adopted for large-scale environmental monitoring programs, in part because they can create a spatially balanced sampling design that allows additional samples to be added or subtracted without compromising the spatial balance (Stevens and Olsen 2003, 2004). The GRTS method is being encouraged by NPS I&M national leadership

(Steve Fancy, personal communication) and has already been adopted in at least one other NPS bird monitoring project (Siegel et al. 2005).

c) Sampling frequency and replication

The survey will have a split-panel design (Table 1), wherein one panel of 18 transects in each large park is visited once every year. An additional 72 transects are divided into four serially alternating panels of 18 transects each. Every year, all 18 transects in one of the alternating panels will be visited in addition to the panel that is revisited annually. Each of the transects in the four alternating panels will thus be visited every four years. In each park, six low-elevation transects, six medium-elevation transects, and six high-elevation transects will be selected for inclusion in the panel that is sampled annually. The remaining transects will be assigned to the four alternating panels, such that each panel includes six low-elevation, six medium-elevation, and six high-elevation transects.

d) Recommended number and location of sampling units

The survey design described above yields 90 transects, each consisting of 14 points, in each large park--18 transects are surveyed annually, and 72 are surveyed every four years. Transect starting points for SEKI and YOSE, selected using the GRTS-based methods described above, are presented in Figure 1 and Figure 2.

Each transect will consist of 14 point count stations, spaced 250 m apart. Transects will 'start' at selected points along park trails, and will extend perpendicularly away from the trail to yield seven survey points in both directions. The first sampling points in each perpendicular direction will be established 125 m from the trail 'starting' point. Experience conducting our inventory projects has shown that seven off-trail points is the maximum number that a crew member can fairly reliably survey during a morning of work in the SIEN's more challenging habitats. Except for instances where off-trail travel is impossible (see Section 2.3c below), individual survey points will thus range from a minimum of 100 m from the nearest trail to a maximum of 1.625 km from the nearest trail.

We also recommend annually surveying an array of points at Devil's Postpile, which could comprise the entire array of 42 points established for the DEPO landbird inventory (Siegel and Wilkerson 2004a), or could be a smaller subset of those points. Even with the full of array of points, a 2-person crew would be able to complete the entire survey in approximately three days.

e) Level of change that can be detected for the amount/type of sampling being instituted

We present a preliminary assessment of statistical power to detect population trends in Chapter 3 of this report.

2.3) Field methods

a) Field season preparations and equipment setup

The first step in preparing for the field season is to recruit and hire a well-qualified crew. The importance of securing a well-qualified crew for this project cannot be understated. During the training period at the beginning of the season, protocols can be taught and bird identification skills can be sharpened, but it is essential that all four members of the Network crew be experienced birders, very physically fit, and comfortable spending extensive time in the backcountry. Every reasonable effort should be made to entice the previous year's observers to return, but it seems likely that at least some new observers will need to be hired every year. We recommend beginning the recruiting process in December to ensure that maximally experienced, qualified observers can be found. Once new observers are hired, they should be sent species lists and other materials that will enable them to be as familiar as possible with Sierra birds and their vocalizations prior to the start of the training session in May.

Beginning in February or March, equipment should be inventoried (including testing of breakable items such as GPS units, radios and water filters) and any needed items should be purchased. Data forms should be printed or copied, and topographic maps (1:24,000 scale) for the year's targeted transects should be printed and assembled. Crew housing needs to be secured at each of the large parks (this process may need to begin earlier if NPS facilities are to be used), and housing, campsites, and other logistic arrangements for the training session need to be made. NPS personnel knowledgeable about back-country conditions in each park should be consulted, to determine (to the degree possible) whether conditions such as washed out bridges, road or trail closures, or unusually heavy snowpack may present novel logistic problems.

b) Sequence of events during field season

We recommend beginning training somewhere between April 25 and May 1, depending on the experience level of the crew. Surveys should begin on or around May 15. The lowest elevation transects are conducted first, with crews gradually moving upslope throughout the season. All surveys should be completed by July 22. The project sampling scheme is built around an assumption that pairs of observers will work six 7- or 8-day sessions, most of which will be spent entirely in the backcountry.

c) Details of taking measurements

A pair of observers will work together to conduct a single, 14-point transect each morning. The first time a transect is surveyed, observers will be given a map and coordinates that indicate a transect 'starting point' that lies on a trail. From this starting point, the two observers will walk 125 m along the cardinal or semi-cardinal directions that most closely approximate perpendiculars to the trail, in opposite directions from one another. Each observer will conduct a point count, and then continue walking in the same direction, conducting another point count every 250 m until seven point counts have been completed. Point counts will begin within 10 minutes of official local sunrise, and must be completed by 3.5 hours after official local sunrise, as bird activity tends to decrease substantially later in the morning.

If a barrier such as a cliff or uncrossable stream is encountered, the observer will return to the last successfully surveyed point and select a new direction of travel. The new direction of travel will be determined as follows:

> The observer assesses the directions defined by the original direction +/- 45º. If both appear traversable, one is randomly chosen, and then followed for the remainder of the transect (unless another barrier is encountered). If one direction is traversable and the other is not, the traversable one is followed for the remainder of the transect. If neither direction is traversable, the observer assesses the directions defined by the original direction +/- 90º, in the same manner as described above.

In some instances--such as when a trail is immediately adjacent to a river-- it may not be feasible for one or both of the observers to walk even 125 m away from the trail. In this situation the observer will conduct the point counts directly on the trail, every 250 m in a pre-determined direction. After each successive point count, the observer will reassess the feasibility of returning to the perpendicular bearing, and if it seems promising, leave the trail to conduct the remainder of the transect off-trail, in the cardinal or semi-cardinal direction that best approximates a perpendicular to the trail. We are confident that conducting some of our transects partly or completely on trails will not unduly bias survey results, as recent work at North Cascades NP has shown that bird detectability during point counts appears unaffected by whether the counts are conducted on or off trails (Siegel et al. *in review*). Additionally, visitor impacts appear light enough along most trail stretches in the SIEN parks that it seems unlikely that trail proximity substantially affects avian community composition or abundance.

On the second and all subsequent visits to a transect, observers will be provided with maps, coordinates, and descriptions indicating the location of all of their survey points.

Although they will work alone, partners will never be more than 3.25 km from one another, and should consequently be able to remain in radio contact throughout the morning. Additionally, observers mark their path with flagging as they walk. In the event of an emergency, observers can thus follow the trail of flags to find their partners. Observers will collect all flagging after they complete their last point count for the morning, and will also comply with any other park regulations on flagging usage.

The first point count will begin within 10 minutes of official local sunrise, and the last point count must be completed by 3.5 hours after official local sunrise. At each point the observer will record the starting time, score the degree of noise interference caused by such factors as flowing water or wind, and then, after a 10-min settling down period to allow the resumption of normal behavior by any birds disturbed by the observer's approach, begin the five-minute point count. Birds observed in the first three minutes will be recorded separately form those observed in the last two minutes, in order to allow comparison with Breeding Bird Survey data, which are based on 3-min counts. Observers will estimate the horizontal distance, to the nearest meter, to each bird detected. These estimations will allow detection probabilities to be calculated as a function of distance for each species, and will therefore allow estimation of absolute density. The observer will also record whether the distance estimate was based on an aural or visual detection, and whether the bird ever sang during the point count. These last two pieces of data may facilitate analysis of a) error associated with estimating distances to unseen birds, and b) estimation of the density of singing males, rather than all birds pooled. Any juvenile birds detected will not be recorded on the point count data form. All adult birds recorded at each point will be noted on the data form, but there will also be a field for observers to indicate that a particular bird was already detected at a previous point. The form will also provide a separate field for tallying 'flyovers', birds that fly above the top of the vegetation canopy, never touch down in the observer's field of view, and do not appear to be foraging, displaying, or behaving in any other way that might suggest a link to the habitat below them.

After completing their seventh point count, observers will follow their own trail of flagging back to the starting point, where they will meet their partners. Along the way they collect the flags, and also collect vegetation information at each of the survey points. The first year a transect is surveyed, the observers will classify the habitat in a 40-m radius circle according to the National Vegetation Classification Standard (NVCS), with modifications for local application at Yosemite and Sequoia and Kings Canyon National Parks (NatureServe 2004). During subsequent visits, observers will verify that the habitat classification is correct, and/or note any substantial changes.

After completing their fieldwork each day, partners will review each other's data forms for missing or incorrectly recorded data, and discuss any interesting or surprising bird detections.

d) End-of-season procedures

At the end of the season the field crew leader will prepare a brief (generally not more than three pages) field season report that:

- -clearly enumerates which transects were completed during the season,
- -describes any logistic difficulties that arose, and explains how they were addressed,
- -clearly documents and explains any diversions from established protocols,
- -points out any interesting or potentially important observations about the parks' bird communities that may have been noted during the field season (e.g. apparent changes in phenology from previous years, or notable changes in apparent abundance of particular species), and
- -provides suggestions for improving the training session or field season logistics in the future.

Crew leader reports will be archived so that they will be available to future crew leaders and to data analysts.

2.4) Data analysis and reporting

a) Overview of database design

Project databases will be formatted in Microsoft Access and will conform to Network standards. To ensure this conformity, the databases will be developed in collaboration with Network data managers.

b) Data entry, verification, and editing

At the end of the field season, all data will be entered into Microsoft Access databases. The project lead will then be responsible for verifying, correcting, and certifying the databases.

c) Reporting schedule and recommendations for routine data summaries and statistical analysis to detect change

We recommend that a summary report be produced annually, with a somewhat more in-depth report produced at least every four years. The annual report should:

- tabulate the number of detections of each species, as well as the number of points and transects and the identity of each point and transect where each species was detected.

- model detectability as a function of distance (or use previously modeled parameters) to produce an adjusted estimate of absolute density for each species detected along each transect.

- summarize temporal trends on the annual panel of transects, by park and network (first four years).

- summarize temporal trends on the annual panel of transects as well as each panel that has been sampled more than once (beginning in the fifth year).

A more in-depth analysis and report at least every fourth year would be desirable. In addition to doing all of the above, the four-year report would also aggregate results from all panels to produce parkwide and Network-wide trend estimates for each species, assess spatial patterns in the density estimates, identify any possible distributional changes within the parks, and perhaps try to place network results within the larger context of bird population changes throughout the Sierra, as measured by regional efforts such as the BBS or MAPS. The report should also evaluate operational aspects of the monitoring program, such as whether any transects need to be eliminated or moved due to access problems, whether the sampling period remains appropriate (the optimal sampling season could conceivably change over time in response to climate change), etc.

d) Data archival procedures

Data management and archival procedures will adhere to Network standards. At the end of the season data will be entered into computer databases and raw data forms will be archived. Once the project lead corrects and certifies the databases, they will be archived.

2.5) Personnel requirements and training

a) Roles and responsibilities

This protocol narrative assumes that a four-person crew (two observers at YOSE and two observers at SEKI) will be available to conduct fieldwork throughout May, June, and most of July. One of the pairs of observers will also need to briefly visit and survey DEPO, unless other personnel are available to conduct the surveys there. The SIEN landbird monitoring crew will be led by a single crew leader who will be principally responsible for training and testing the crew, providing quality assurance and trouble-shooting logistic problems throughout the field season, preparing the end-of-season field report, and conducting transect surveys with the three other crew members.

b) Qualifications

The crew leader each year must be a highly skilled birder with experience conducting VCP point counts and familiarity with Sierra Nevada birds and plant communities. Familiarity with one or more of the SIEN parks is also desirable. Ideally, the crew leader will have supervised field crews before and/or previously served as a SIEN landbird monitoring crew member. Finally s/he must be very physically fit and prepared to spend extended periods of time in the backcountry.

The other crew members should have prior birding experience, including substantial experience with Sierra birds or a demonstrated ability to quickly learn the songs and calls of new bird species. They must also be very physically fit and prepared to spend extended periods of time in the backcountry. Substantial backpacking experience and experience conducting VCP point counts are also desirable.

c) Training procedures

A comprehensive and well-designed training program is critical to the success of this project, as it will maximize observer consistency--both within and between years. Past experience has shown us that particularly experienced or talented crew members can be adequately trained in two weeks or less, but we recommend allowing up to three weeks for the training period, to maximize the likelihood that all observers will be qualified to conduct point counts at the end of the training session. The training session should provide instruction in the following topics:

- bird identification by sight and sound
- conducting point counts
- estimating distance to birds
- plant identification and habitat assessment
- completing field forms
- orienteering
- first aid and backcountry safety

At the end of the training session, all observers should be able to pass a rigorous bird identification exam, which will certify that they can competently identify by sight and sound all species they are expected to encounter during the field season.

2.6) Costs and Operational requirements

a) Annual workload and field schedule

Crew training should begin between April 25 and May 1 each year. Transects surveys should begin around May 15. The sampling design assumes that in each large park, two observers will work together to survey six groups of six transects, for a total of 36 transects. Each group of transects requires two observers seven or eight days to complete. We recommend providing observers with three days off after surveying each group of transects.   Sampling will begin with the lowest-elevation group of transects in each park, and observers will gradually progress upslope throughout the season. The final transect must be completed by July 22.

In addition to the field season, other annual tasks associated with this project include:

- entering data and correcting and certifying the database,
- analyzing the data,
- preparing the annual report, and
- preparing for the next field season.

b) Facility and equipment needs

This project requires minimal special facilities and equipment. The crew will require housing in the vicinity of both large parks for the duration of the season. Necessary equipment includes backpacking gear and binoculars (which crew members should provide for themselves), as well as GPS units, radios, water filters and miscellaneous smaller items. Computer access is necessary during the training session, and helpful throughout the season. One or more laser rangefinders may be helpful during training, but is not strictly necessary.

c) Startup costs and budget considerations

This project will incur fairly minimal startup costs beyond the present contract, which funds the development of this protocol narrative, as well as the production of a spatially explicit sampling design for each park. If the project is selected, more detailed Standard Operating Procedures (Oakley et al. 2003) will likely be required, but this should not be a large expense.

If the Network decides to contract the survey work out to an external cooperator, then no additional personnel should need to be hired. We estimate the annual cost (in 2005 dollars--not accounting for salary increases or inflation between now and the onset of the program) for The Institute for Bird Populations to prepare for a field season, deploy a four-person crew (two people in each large park), survey 72 transects (36 in each large park), survey a small array of points at DEPO, enter the data into electronic databases, analyze the data, and produce an annual report would be approximately $67,000.

3) Using Landbird Inventory Data to Assess the Statistical Power of the Landscape-level Monitoring Program

3.1) Introduction

Recent efforts to inventory breeding landbirds throughout the SIEN (Siegel and DeSante 2002; Siegel and Wilkerson 2004a, 2004b) provide a rare opportunity to use pilot data to assess statistical power of the proposed landscape-level monitoring program. Although the proposed program would be implemented in both SEKI and YOSE, here we focus our power assessments on SEKI because the methods used in the SEKI landbird inventory more closely match the proposed monitoring methods (at YOSE we recorded distance estimates only in the second year of the study, and the final report included densities based on 50-m radius point counts, but these density estimates did not otherwise include adjustments for detectability). We nevertheless expect very similar results at YOSE, except for a small handful of species that are considerably more abundant at one park than at the other (i.e. more Hermit Warblers and Hammond's Flycatchers at YOSE, more Wrentits at SEKI). It should be noted that our power assessment results pertain to parkwide population trends only; statistical power for detecting regional trends (i.e. pooling data from YOSE, SEKI and perhaps even DEPO) will likely be greater, although we do not test this in the current analysis.

The development of analytical procedures for panel designs in ecological monitoring is a young and rapidly developing field (Urquhart and Kincaid 1999; McDonald 2003). Efforts are currently underway to develop analytical routines for a proposed landbird monitoring program in the North Coast/Cascades Network (NCCN), using cutting-edge statistical techniques (TerraStat Consulting Group, *in preparation*) that address the complexities and maximize the benefits involved in using panel designs to monitor temporal trends.

A power analysis assessment that incorporates the complexity inherent in panel designs is unfortunately well beyond the scope of the present effort; indeed, developing a framework for analyzing the SEKI data if this program is adopted will likely require substantial consultation from a statistician with expertise in applications for panel designs. Alternately, it may be possible to simply adapt existing products from the NCCN work or similar efforts. In any case, for the present effort we found it necessary to simplify our power analysis by eliminating the analytical complexity introduced by the panel design.

3.2) Methods

a) Estimating statistical power using TRENDS

We assesses statistical power as though we will not be using the augmented, serially alternating panel design described in Chapter 2 of this report. Recall that our proposed design for each park includes 90 transects of 14 points each-- 18 transects will be sampled annually, while the remaining 72 transects will be distributed among four additional panels (18 transects each) that will each be sampled every four years. In any given year, then, a total of 36 transects will be surveyed: 18 from the annual panel and 18 from one of the serially alternating panels. We conducted our power analysis as though *the same 36 transects will be sampled each year*. We do not know whether this assumption ultimately inflates our power estimates (because some of the transects will actually be sampled every five years rather than every year) or decreases them (because the true number of transects and points sampled will be 90 and 1260, respectively, rather than 36 and 504, as assumed in the power analysis).

This assumption allowed us to utilize the widely-used power analysis software TRENDS 3.0 (Gerrodette and Brandon 1993, 2000) to estimate the number of years needed to achieve an acceptable level of statistical power for detecting a species-specific population decline of 4% per year. We used our SEKI inventory data and the general approach and equations in Buckland et al. (2001) and Buckland et al. (2004) to predict the species-specific coefficient of variation (CV) we would obtain from our annual monitoring transects. To do this, we first used the software DISTANCE 4.0 Release 2 (Thomas et al. 2002) to model detectability and estimate parkwide density (pooling data from all habitats) for each species detected at least 60 times during our inventory point counts, as distance-sampling experts generally advise that at least 60-80 detections are necessary for reliably modeling the relationship between detection probability and distance from the observer (Buckland et al. 2001). We amassed 60 or more detections of 43 species (Table 2). We set the data filter in DISTANCE to truncate the largest 10% of observations (Buckland et al. 2001), and then fit models using the half-normal key function and both the cosine and polynomial series expansions. We used the Akaike Information Criterion (AIC) to select among models with different forms and numbers of expansion terms (Akaike 1973; Burnham and Anderson 1998), then used the CV of each species' density estimates obtained from the inventory data to predict the species-specific CV we would obtain under a monitoring scenario that comprised 504 sampling points (36 transects of 14 points each), using the following formula adapted from equation 7.14 in Buckland et al. (2001):

$$\text{expected CV} = ((n_0 * (\text{observed CV})^2 * k_0)/(k * n_0))^{0.5}$$

where: expected CV = CV of annual density estimate in monitoring program,
n_0 = number of detections in pilot study,
observed CV = CV of density estimate from pilot study,
k_0 = number of points in pilot study, and
k = annual number of points in monitoring program.

For each species we entered the expected CV into TRENDS, and set alpha (the probability of not detecting a trend when one really exists) at 0.2 and 1-beta (the probability of correctly detecting a real trend) at 0.8. These parameters are consistent with most guidelines for ecological monitoring programs, which suggest setting alpha equal to beta, and placing them both within the range of 0.1-0.2. We assumed that the CV would change over time in proportion with the square root of density, population change would be exponential (rather than linear), and that statistical tests would be two-tailed.

We also used TRENDS to explore how statistical power for trend detection would change over time for each species. To do this we kept the parameter settings as described above, except we specified the number of years of monitoring (5, 10, 15, 20, 25, and 30 years, respectively) and then had the software compute the statistical power after each additional five-year interval. We used the software package SigmaPlot (SPSS 1999) to fit spline curves through the six points for each species.

<u>b) Predicting the number of transects with detections of each species for the profile-summary approach</u>

Although we believe our TRENDS-based approach should provide a relatively good approximation of monitoring program's statistical power, we acknowledge that the panel design will require future data analysts to take a somewhat more complicated approach to trend estimation, such as the profile-summary approach (TerraStat Consulting Group 2002), in which the data might be analyzed by transect rather than point, with the profile for each transect consisting of the temporal record of bird densities for that discrete transect, and the slopes of the transect-specific regressions treated as replicate measurements of park-wide trends and tested for differences from zero using a modified *t*-test approach. Although a statistical power assessment based on this sort of analysis is beyond the scope of this report, we were nevertheless interested in at least predicting the number of transects on which each species would be detected, and hence, the number of profiles available for any such analysis.

To estimate the number of 14-point transects on which we would expect to detect each species, we again turned to the SEKI inventory data. The simplest approach would have been to simply determine the proportion of inventory transects on which each species was detected, and to assume that the proportion would remain similar for the monitoring transects. The complicating factor, however, is that the proposed monitoring transects will all comprise 14 survey points, whereas the length of inventory transects was highly variable (5-13 points per transect), with *no* transects containing 14 points. Before we could predict the number of monitoring transects on which each species will be detected, we therefore first needed to account for the relationship between number of points on a transect and likelihood of detection for each species. To create a uniform dataset for doing this, we worked with just the 177 SEKI inventory transects that included at least seven points, and discarded any points on these transects beyond the seventh point. We then assessed the proportion of transects on which each species was detected a) at the first point, b) at the first or second point, c) at the first, second, or third point, and so forth up to seven points. We did this for each species that was detected at least ten times on the first seven points of these 177 transects.

We then used these seven proportions for each species to fit a logarithmic function modeling the relationship between transect length and the proportion of transects on which each species is detected:

$$y = y_0 + a(\ln\{x\})$$

where y = the proportion of transects where a species was detected, x = the number of points per transect, and y_0 and a are constants. Once we had species-specific values for y_0 and a, we solved for y where x = 14 points, and then multiplied the resulting probability by 90 transects to obtain a prediction of the number of monitoring transects at SEKI on which we would expect to detect each species.

3.3) Results and Discussion

a) Estimating statistical power using TRENDS

Of the 43 species for which we had adequate data to model detectability and predict a CV for the monitoring program, 22 of them were predicted to reach the threshold of (1-beta) = 0.8 within 20 years of monitoring, and 9 species were predicted to reach the threshold within just 10 years (Table 2). The average length of time for the entire suite of 43 species was approximately 21 years. Spline curves indicating the predicted change in statistical power for each species over time are presented in Figure 3. All but three of the species curves (Red-breasted Nuthatch, MacGillivray's Warbler, and Green-tailed Towhee) reached (1 - beta) = 0.8 within the 30-year interval we examined, and twenty-two of them reached (1 - beta) = 1.0.

The precision of our density estimates clearly plays a large role in determining statistical power of the monitoring program. Precision of density estimates from program DISTANCE is primarily driven by two factors: 1) *n*, the number of birds detected, and 2) *h(0)*, the slope of the probability density function of detection distances, evaluated at zero distance (Buckland et al. 2001). In general, more commonly detected species yielded density estimates with lower CVs, but this was far from a consistent rule, due to the effect of the shape of the probability density function.

b) Predicting the number of transects with detections of each species for the profile-summary approach

Figure 4 presents the relationship between the number of points per transect and proportion of transects with detections for each species. Although the proportions obviously varied greatly between species, the logarithmic function appears to have fit the data reasonably well for most species.

The data suggest we can expect around 45 species to appear on more than ten transects (Table 3), and around 29 species to appear on more than 20 transects (Table 3). Although we based this exercise solely on SEKI data, we expect that for most species, results at YOSE would be similar, and that if the goal were to detect regional, rather than park-specific trends, the number of transects for most species would be approximately doubled.

As with the results of our analysis based on TRENDS, the predicted numbers of transects for a large number of species appear quite promising, and suggest that the proposed sampling design provides a cost-effective means of monitoring a large, diverse suite of landbird species with a reasonably high power to detect population changes.

4) Using the Breeding Bird Survey (BBS) to Assess Which Sierra Habitats are Under-sampled by Current Large-scale Bird Monitoring Efforts

4.1) Introduction

The SIEN network covers an enormously broad range of plant communities and environmental conditions, and is home to well over 120 species of breeding birds. Although we recommend pursuing the ‘landscape level’ landbird monitoring program described in Chapter 2 of this report, another reasonable approach is to focus resources on monitoring birds in one or more selected habitats or bird communities. One rational way of choosing habitats to target is to ask which habitats are least well-monitored by existing efforts throughout the Sierra Nevada.

The most spatially extensive bird monitoring program currently operating in the Sierra Nevada is the Breeding Bird Survey (BBS). The BBS is an annual, volunteer-based point count survey coordinated by the Biological Resources Division of the USGS and the Canadian Wildlife Service. Droege (1990) and Peterjohn and Sauer (1993) provide detailed descriptions of the survey’s methodology and rationale. In brief, the survey consists of a continent-wide array of roadside point count transects, or routes. Each route is 24.5 miles long, and comprises 50 point counts at 0.5 mile intervals. Expert volunteer observers conduct point counts once each year during the peak of the breeding season (June in the Sierra), recording numbers of every species detected within a quarter mile radius. However, the BBS has a number of important limitations, including:

- the survey is based on raw counts of birds, with no means of correcting for variable detectability across species or habitats.

- BBS point counts are conducted exclusively at roadsides, which often include a large proportion of fragmented and edge habitats, and may poorly represent the larger landscape. This focus on roadside habitats likely biases resulting descriptions of avian community composition, by ‘over-counting’ species associated with habitats commonly bisected by roads, and ‘under-counting’ species associated with habitats that are rarely bisected by roads (O’Connor 1992; DeSante and George 1994).

- In most analyses of BBS data, the route, rather than the individual point, has been treated as the unit of analysis; trends for particular species are calculated according to cumulative results from all 50 points along a route. This is problematic because 25-mile long routes generally cross multiple major habitat types. This ‘broad-brush’ approach severely limits inferences as to which specific habitats harbor declining or increasing bird populations. This situation cannot be improved upon until reliable habitat data exist for individual stop locations, which will allow habitat-specific analysis of bird count data.

For all these reasons we urge the SIEN to adopt a spatially extensive landbird monitoring program that avoids the pitfalls of the BBS.

In 2002 The Institute for Bird Populations initiated a project to conduct ground-based habitat classification at each of the BBS stop locations along the 33 BBS routes (although several of the routes were inactive at the time) that lay within the Sierra Nevada, as defined by the 'Jepson' boundaries for the Sierra Nevada established by Hickman (1993) and California Gap Analysis Project (1998). We hoped that by classifying and photographing the habitat at these points we could:

> -determine which habitats are or are not well sampled by the BBS, and thereby provide guidance for future monitoring efforts to focus scarce resources on those habitats most in need of monitoring.
>
> -facilitate habitat-specific analysis of Sierra BBS data.
>
> - provide a benchmark dataset for assessing future ecological changes throughout the Sierra, in the form of habitat classifications and digital photographs taken at all of the survey points. The value of archival landscape photographs has been amply demonstrated by Gruell (2001).

Unfortunately our funding in the second year of the study was insufficient to finish the project-- we ultimately fell short of our goal of surveying all 33 of the Sierra's routes, instead completing work on just 28 of them (Siegel 2002; Siegel and Wilkerson 2003). We were also unable to complete analytical work on the project. Here we complete some of the intended analytical work, in order to provide some insight for the SIEN decision-making process. Our hope is that a better understanding of which habitats are or are not well-sampled by the BBS may provide a rationale for which habitat or habitats to target if the network elects to reject the landscape-level monitoring approach descbribed in Secition 2, and instead target a particular habitat or habitats for bird monitoring.

4.2) Methods

During the summers of 2002 and 2003 we located points along survey routes with the aid of route maps and stop descriptions obtained from the individual BBS observers. At each survey point we classified the habitat according to the California Wildlife Habitat Relationships (CWHR) classification system (CA Dept. of Fish and Game 1988, 1999), including plant community type, seral stage, and cover class. Because roads often follow ecotones or divide areas with different management histories, we classified habitats on each side of the road separately. Our assessments are based on 150 m radius semi-circles on either side of the road, centered on the BBS survey point. For each side of the road we recorded a primary habitat classification, as well as additional classifications for any comprising a third or more of the semi-circle. We also recorded habitat inclusions that were smaller but were nevertheless likely to affect local bird community composition recorded at the BBS point.

For the 28 Sierra BBS routes we visited (Table 4), we tallied the number of point count survey stations where at least half the area surveyed by the point count (the left side of the road, the right side of the road, or both sides of the road) was dominated by each CWHR habitat type.

We then used the Gap Atlas of Mainland California (California Gap Analysis Project 1998) to determine the percent of the overall Sierra Nevada region, using the 'Jepson' boundaries defined by Hickman (1993) and California Gap Analysis Project (1998). We then used two metrics for evaluating which habitats are undersampled by the BBS:

1) the absolute number of points represented by a particular habitat, and

2) the difference between the percent of the Sierra covered by a particular habitat and the percent of BBS points represented by that habitat.

4.3) Results and Discussion

Twenty-two of the 43 CWHR habitats mapped as occuring in the Sierra were represented by fewer than 20 points along all the BBS routes we visited (Table 5). Habitats in this group that cover more than negligible portions of the SIEN parks include two low-elevation habitats (Mixed Chaparral and Chamise-Redshank Chaparral), two high-elevation habitats (Alpine Dwarf-Shrub and Subalpine Conifer), and two habitats that may span large elevational gradients (Barren and Wet Meadow). Each of these habitats, with the possible exception of Barren, host distinctive bird communities with numerous species that are not well-monitored by the BBS, and would therefore be reasonable choices for narrowly focused bird monitoring efforts.

Another way of assessing which Sierra habitats are poorly sampled is to look not at the absolute number of points representing each habitat, but instead to consider how well a habitat is sampled *relative to its aerial extent in the Sierra Nevada*. We assessed this metric for each habitat (Table 5), and found that for seven habitats, the percent cover throughout the Sierra Nevada was at least three percentage points greater that the percent of BBS points representing that habitat. Of these seven habitats, three account for more than negligible portions of the SIEN parks: Barren, Blue Oak Woodland, and Subalpine Conifer. Again all of these habitats host distinctive bird communities with numerous species that are not well-monitored by the BBS, and would therefore be reasonable choices for narrowly focused bird monitoring efforts.

Including all habitats that have more than negligible coverage in the SIEN parks, are under-sampled by the BBS in either of the senses described above, and host distinctive bird communities worthy of targeted monitoring, the full list is:

1. Blue Oak Woodland
2. Chamise-Redshank Chaparral
3. Mixed Chaparral

4. Alpine Dwarf-Shrub
5. Subalpine Conifer
6. Wet Meadow

Habitats 1-3 could be sampled together by monitoring efforts focused on the lowest elevation zone in the SIEN. One substantial disadvantage to focusing on these habitats, however, is that they are well-represented only at SEKI, and with the exception of Mixed Chaparral, are nearly or completely absent from the other two SIEN units. Additionally, the extensive shrub canopy (which can be very difficult to move through) and the presence of poison-oak (*Toxicodendron diversilobum*) make the chaparral habitats particularly challenging environments for conducting bird survey work.

Habitats 4 and 5 could be sampled together by monitoring efforts focused on the highest elevation zone in the SIEN. This region hosts a bird community that is especially poorly sampled by the BBS. However, it also poses substantial logistical challenges for any targeted bird monitoring work. Variable annual snowpack means that the timing of field crew access to subalpine and alpine habitats may vary substantially from year to year, especially in areas that are best accessed from trailheads east of the Sierra crest. Even in years with moderate to low snowpack, the temporal window of the sampling season-- the time interval between when the areas are first accessible by foot and when most birds diminish their territorial singing-- may only be three or four weeks long.

Habitat 6, Wet Meadow, is perhaps the best choice for narrowly focused monitoring efforts, as it presents few logistical obstacles compared with low-elevation or high-elevation habitats. Additionally, wet meadows are disproportionately important (relative to their aerial extent) to a large number of montane bird species (Siegel and DeSante 1999), and their bird communities may be particularly sensitive to management actions or natural disturbances, as discussed in Chapter 5 of this report.

5) Landbird Monitoring Alternative B: Monitoring Population Trends and Status of Meadow-associated Landbird Species

5.1) Background and objectives

a) Background and history

The importance of montane meadows to the Sierra avifauna is difficult to overstate. A long, taxonomically diverse list of Sierra species depends critically on meadows for nesting and/or post-breeding habitat. Many of these meadow-breeding species appear to be declining across the Sierra (Siegel and DeSante 1999), and two of them, Willow Flycatcher and Great Gray Owl, are included on California's Endangered Species List. Although Willow Flycatcher in particular is no longer expected to occur in many SIEN meadows, these listed species may serve as bellwethers for future problems with other meadow-associated species.

Many additional bird species depend on meadow habitat to varying degrees for foraging grounds and/or water sources (DeSante 1995). In addition to providing habitat for meadow-nesting species, Sierra meadows also serve as crucial molting and pre-migration staging areas for juveniles and adults of a broad array of species that may or may not nest in meadows (DeSante 1995; Siegel et al. 2003), including House Wren, Orange-crowned Warbler, Nashville Warbler, MacGillivray's Warbler, Yellow-rumped Warbler, Hermit Warbler and Dark-eyed Junco. At least two additional species, Rufous Hummingbird and Wilson's Warbler, depend on Sierra meadows as important stopover sites during fall migration (Gaines 1992). Finally, the population density of many forest-inhabiting species is often highest near meadow edges, even among species that only rarely venture into the meadows (DeSante 1995).

Throughout much of the Sierra, historic and current human activities have substantially altered meadow hydrology and vegetation (DeBenedetti and Parsons 1979; Ratliff 1985; Hagberg 1995; Moyle 1996). Severe overgrazing between the late 1800's and around 1930 caused largescale erosion and gully formation (Menke et al. 1996; Kattelman and Embury 1996). In addition to trampling nests (Skovlin 1984), heavy grazing in meadows can affect meadow-associated birds by changing the vegetation structure and composition (Dobkin 1994), facilitating forest encroachment (Odion et al. 1990; Ohmart 1994; Menke et al. 1996; Kattelman and Embury 1996), and attracting cowbirds (Rothstein et al. 1980; Verner and Ritter 1983; Rothstein et al. 1984; Laymon 1987). Other anthropogenic factors that have altered meadow hydrology and vegetation include road construction and logging of adjacent forest stands.

Although the worst abuses were halted, meadows across the national forests were still heavily grazed until the 1970's, and locally heavy grazing persists today. Indeed, the management of montane meadows on public lands throughout the Sierra remains a highly contentious issue, as riparian areas in general tend to be focal points of conflict among competing uses for livestock grazing, timber harvest, recreation, and water diversion for other uses (Johnson et al. 1985).

Numerous studies have demonstrated than many meadow-breeding bird species can be quite sensitive to the habitat changes that human activities and livestock grazing can produce (Taylor 1986; Taylor and Littlefield 1986; Harris et al. 1987; Knopf et al. 1988; Cicero 1997; Dobkin et al. 1998). Although meadows in the present-day national parks generally face few new threats of the kind described above, factors including visitor impacts, packstock grazing, and anticipated climate change all may affect habitat conditions in SIEN meadows. Additionally, even SIEN meadows that do not face significant risks due to visitor impacts or packstock grazing are still well worth monitoring as reference sites for assessing the effects of meadow management on bird populations throughout the rest of the Sierra Nevada; monitoring conditions at reference sites for comparison with more heavily managed sites throughout the region is in itself an important use of NPS resources (Silsbee and Peterson 1991).

b) Rationale for selecting this resource to monitor

Meadow bird populations provide an excellent resource to monitor for several reasons. First, landbird monitoring is particularly efficient, in the sense that many species can be monitored simultaneously with the same survey protocol, and costs are relatively low. This capacity to capture a fairly broad sector of park resources (i.e. numerous bird species) elevates the desirability of monitoring landbirds over some other taxa, for which expensive projects may only monitor a single species (Croze 1982). Relative to other animal taxa, landbirds are easy to detect during the breeding season. They generally occupy a high position on the food web and they provide important ecological functions such as dispersing seeds and keeping insect populations in check, making them good indicators of changes in ecosystems (Furness et al. 1993; Greenwood et al. 1993). Meadow-associated bird species may be particularly sensitive to changes in vegetation structure and composition, making them sensitive indicators of broader ecological changes in meadows (Fleet and Sanders 1987; Harris et al. 1987; Cicero 1997; Wilkerson and Siegel 2001).

Well-developed, standardized data collection and analytical procedures for estimating landbird population density already exist (Buckland et al. 2001), and will facilitate comparisons among SIEN meadows as well as comparisons between SIEN meadows and data from other efforts. Substantial knowledge about the distribution and habitat requirements of meadow birds in the Sierra Nevada (e.g. Beedy and Granholm 1985; Gaines 1992; Siegel and DeSante 1999), as well as more specific information about the status of meadow birds in the SIEN, also already exists and has informed our project design. Spatially extensive landbird inventories have been completed at Yosemite National Park (Siegel and DeSante 2002) and Devil's Postpile National Monument (Siegel and Wilkerson 2004a), and nearly completed at Sequoia and King's Canyon National Park (Siegel and Wilkerson 2004b; Siegel and Wilkerson *in preparation*). A related project assessed breeding and post-breeding bird communities in nearly 100 meadows at YOSE and SEKI, and then selected the most critical 18 meadow 'hotspots' in each park (Wilkerson and Siegel 2001). Finally, MAPS (Monitoring Avian Productivity and Survivorship) stations continue to collect demographic data at multiple meadows throughout all the three SIEN parks (Gates and Heath 2003; DeSante et al.

2004, 2005). If some or all of the MAPS stations continue to collect demographic data concurrently with the spatially extensive efforts described in this project narrative, the inferences resulting form each project will synergistically enhance one another.

Landbirds hold high and growing public interest (Cordell et al.1999; Cordell and Herbert 2002) and are perhaps the most visible faunal component of park ecosystems. Meadows are among the park habitats that hold the greatest attraction to visitors, and are also the most likely habitats to sustain substantial visitor impacts.

Because of their limited aerial extent, meadow habitats are poorly surveyed by the Breeding Bird Survey in the Sierra Nevada, accounting for just 15 out of 1,386 Sierra BBS points we visited (see Chapter 4 of this report). Yet the importance of meadow habitat to Sierra birds is disproportionate to its area in the Sierra in general and the SIEN parks in particular.

Finally, the SIEN is considering undertaking long-term monitoring of a variety of other taxa and/or ecological processes associated with montane meadows (R. Mazur, personal communication). Monitoring bird populations at montane meadows may thus allow for a) additional inferences about relationships between birds and other taxa or ecological processes, and b) substantial cost savings if data for multiple projects could be collected at the same meadows by one crew.

c) Measurable objectives

The primary objective of this monitoring project is to determine trends in the abundance of meadow-dependent landbird species (including passerines, near-passerines, and galliformes) throughout accessible areas of the SIEN parks during the breeding season. For commonly detected species, we will be able to achieve park-level inference, allowing comparisons between trends at the different parks. A shared methodology between all three parks across the SIEN will ensure Network consistency and allow us to avoid the pitfalls that can make comparisons between parks difficult or misleading (Quinn and van Riper 1990; Sauvajot et al. 1990; Silsbee and Peterson 1991). For some rarer species that occur in only a limited number of meadows, making inferences on population trends may not be possible at the geographic scale of the individual park, but may be possible at the network-wide scale.

A secondary objective of the project is to track changes in the distribution of meadow-dependent landbird species throughout the parks during the breeding season. This objective provides an additional metric for assessing changes in meadow bird communities throughout the Network, as some important ecological changes, such as populations moving upslope in response to climate change, may not necessarily be discernible by simply looking at aggregate population trends.

The project's third objective will be to track changes in the abundance and distribution of forest bird species that cannot be said to be meadow-dependent, but nevertheless frequent meadow-forest edges.

5.2) Sampling design

a) Rationale for selecting this sampling design over others

In concordance with other NPS bird monitoring protocols that have recently been developed or are currently under development (Coonan et al. 2001; Peitz et al. 2002; Siegel et al. 2005), this protocol surveys landbirds with 5-minute, variable circular plot (VCP) point counts (Reynolds et al.1980; Fancy 1997; Nelson and Fancy 1999; Buckland et al. 2001, Rosenstock et al. 2002). VCP point counts rely upon distance sampling (Buckland et al. 2001), which facilitates the estimation of detection probability--a parameter that may vary greatly by species, habitat, observer, or other factors. Estimates of detection probability permit the estimation of absolute density of birds in the area surveyed, a much more meaningful metric than the relative abundance indices that can be produced without distance sampling.

In this planning document we specify neither particular meadows to sample nor a method for selecting such meadows. One of the biggest advantages of choosing to focus landbird monitoring efforts on birds at montane meadows is that study sites can be co-located with study sites for other long-term studies tracking populations of other meadow-associated taxa or ecological processes at meadows. For this reason, any meadow sampling strategy will likely have to represent a balance between the sampling requirements of a variety of projects, and until those projects are defined and prioritized, developing a sampling framework and selecting particular meadows will not be fruitful.

We can, however, offer some landbird-oriented considerations that should be taken into account when selecting meadows for any effort to monitor multiple taxa and/or processes at meadows:

1) *elevational gradient*. Both large parks span enormous elevational gradients, making park meadows quite diverse with respect to avian community composition, breeding phenology, and average date of accessibility by field crews. Any sampling framework will need to explicitly account for these elevational gradients.

2) *meadow size*. The majority of areas in the parks that are mapped as meadows represent very small habitat patches, often incorporating well under 5 ha. We consider 5 ha of contiguous meadow habitat to be the bare minimum sampling threshold for worthwhile surveys of meadow birds. Patches of habitat smaller than 5 ha are a) unlikely to accommodate more than two point count stations (assuming point count stations must be at least 200 m a apart) and b) considerably less likely than their larger counterparts to host many of the meadow-associated bird species of interest. For both of these reasons, sending field crews to survey small, widely-scattered patches of meadow habitat is an inefficient use of resources, and is unlikely to yield many detections of most species of interest.

3) *rarity of many species of interest*. Some meadow-dependent species, such as Yellow Warbler and Lincoln's Sparrow, are sufficiently rare that they may not be

adequately sampled by any random or systematic selection of the Network's meadows. We therefore recommend that any sampling regime be augmented with meadows from the list of 18 'high priority' meadows designated in each large park during our previous meadow inventory efforts (Wilkerson and Siegel 2001). These meadows are all known to contain particularly high quality habitat, and to host breeding populations of high-interest species. These non-randomly selected meadows will likely not be able to contribute to larger park-wide or Network-wide trend estimates, since they will not have been drawn from the park-wide sets of meadows, but they will help ensure that we have at least some information for assessing the status and trends (albeit without truly being able to make inference to conditions in the Network's unsampled meadows) of some of the rarer species. Of course it is possible (even likely) that some of the 'high priority' meadows will be selected anyway by whatever meadow sampling regime is developed, in which case they would contribute to the larger trend estimates.

<u>b) Site selection</u>

> <u>i) Criteria for site selection; define the boundaries of the population being sampled</u> Sampling will take place during the breeding season only (mid May through the third week of July). Crew members in each park will survey the lowest elevation meadows at the beginning of the field season, and then work their way upslope gradually as the season progresses. This will ensure that all meadows are surveyed near the peak of the breeding season for the elevation zone they represent. Targeted species will include all bird species that utilize montane meadows for breeding and/or foraging, as well as forest species that occur in high numbers around meadow edges during the breeding season.
>
> <u>ii) Procedures for selecting sampling locations; stratification, spatial design</u> As explained above, we are unable to recommend a method for selecting specific meadows at this time, because any meadow sampling regime will likely need to accommodate the sampling requirements of other taxa and/or ecological processes. Selecting specific meadows to sample cannot proceed until those requirements are established.

<u>c) Sampling frequency and replication</u>

Sampling frequency and replication will by necessity depend on the sampling framework that is developed. Sampling frameworks that select more accessible meadows, or clumps of meadows in close proximity with one another, will yield larger potential sizes than frameworks that yield a highly dispersed sample, given equivalent crew sizes. Under a scenario where meadows are particular easy to access, a two-person crew may be able to survey as many as 36 meadows per year. Other sampling designs may accommodate sampling substantially fewer meadows per year. In any case, we recommend using a serially alternating panel design, augmented with a panel of annually surveyed meadows (Urquhart et al. 1998; Siegel et al. 2005) to ensure approximately half of the annual survey effort will be devoted to surveying meadows that are revisited annually, while the remaining survey effort will be devoted to one of several panels of additional meadows that will each be sampled every several years. A panel design with effort split approximately evenly between annually revisited transects and transects in the four-year serially alternating panels allows a much larger number of transects (and regions of the parks) to be included in the sampling scheme than if each transect were to be revisited annually, but still allows for a reasonable amount of year-to-year continuity (Breidt and Fuller 1999; Urquhart and Kincaid 1999; McDonald 2003).

We also recommend annually sampling Soda Springs Meadow at DEPO, so that annual sampling efforts are truly Network-wide, and do not exclude DEPO.

d) Recommended number and location of sampling units

The number and location of meadows to survey will likely depend in large part on the considerations necessary for co-locating samples with those for other taxa, and therefore cannot be determined at this time.

e) Level of change that can be detected for the amount/type of sampling being instituted

The statistical power of this monitoring program is unknown. Although our meadow inventory work (Wilkerson and Siegel 2001) would seem to provide pilot data suitable for exploratory analyses of statistical power, at least two issues severely limit our ability to use the data for this purpose. First, the meadows we surveyed in the meadow inventory effort were not randomly selected; rather, because our aim was to identify the parks' 'best' meadows for birds, we deliberately selected meadows we thought were most likely to host large numbers of meadow-dependent birds. We believe that any power analysis based on this subset of meadows would greatly overestimate our encounter rate of birds in randomly selected meadows. The second limitation is that our meadow inventory project did not incorporate distance sampling, so the density estimates we produced may not be comparable to what would be obtained using the proposed distance sampling methods.

5.3) Field methods

a) Field season preparations and equipment setup

The first step in preparing for the field season is to recruit and hire a well-qualified crew. The importance of securing a well-qualified crew for this project cannot be understated. During the training period at the beginning of the season, protocols can be taught and bird identification skills can be sharpened, but it is essential that all four members of the Network crew be experienced birders, very physically fit, and comfortable spending extensive time in the backcountry. Every reasonable effort should be made to entice the previous year's observers to return, but it seems likely that at least some new observers will need to be hired every year. We recommend beginning the recruiting process in December to ensure that maximally experienced, qualified observers can be found. Once new observers are hired, they should be sent species lists and other materials that will enable them to be as familiar as possible with Sierra birds and their vocalizations prior to the start of the training session in May.

Beginning in February or March, equipment should be inventoried (including testing of breakable items such as GPS units, radios and water filters) and any needed items should be purchased. Data forms should be printed or copied, and topographic maps (1:24,000 scale) for the year's targeted transects should be printed and assembled. Crew housing needs to be secured at each of the large parks (this process may need to begin earlier if NPS facilities are to be used), and housing, campsites, and other logistic arrangements for the training session need to be made. NPS personnel knowledgeable about back-country conditions in each park should be consulted, to determine (to the degree possible) whether conditions such as washed out bridges, road or trail closures, or unusually heavy snowpack may present novel logistic problems.

b) Sequence of events during field season

We recommend beginning training somewhere between April 25 and May 1, depending on the experience level of the crew. Surveys should begin on or around May 15 in Yosemite and perhaps a bit later at SEKI, where there are very few truly low-elevation meadows. The lowest elevation meadows should be surveyed first, with crews gradually moving upslope throughout the season. All surveys should be completed by July 22. The project sampling scheme is built around an assumption that pairs of observers will work six 7- or 8-day sessions, some of which may be spent entirely in the backcountry.

c) Details of taking measurements

The first time a meadow is visited, the point count observer will designate permanent locations of point count stations. Points will be spaced 200 m apart, and must be at least 20 m from the meadow edge. Woody riparian vegetation such as willow thickets or stands of aspen or alder that are adjacent to a meadow will be considered part of the meadow.

For all but the largest meadows, points will be arrayed in a manner that allows the greatest number of points to be fit into the meadow. In the few cases where a meadow might hold more than 15 points, a portion of the meadow (large enough to contain 15 survey points) will be randomly selected. GPS units and topographic maps will be used to collect coordinates of all survey points, which will then be provided to observers in successive years.

The first point count begins within 10 minutes of official local sunrise, and the last point count must be completed by 3.5 hours after official local sunrise. At each point the observer records the starting time, scores the degree of noise interference caused by such factors as flowing water or wind, and then begins the five-minute point count. Birds observed in the first three minutes are recorded separately from those observed in the last two minutes, in order to allow comparison with Breeding Bird Survey data, which are based on 3-min counts. Observers estimate the horizontal distance, to the nearest meter, to each bird detected. These estimations will allow detection probabilities to be calculated as a function of distance for each species, and will therefore allow estimation of absolute density. The observer also records whether the distance estimate was based on an aural or visual detection, whether the bird ever sang during the point count, and whether the bird was inside the meadow or beyond the meadow edge when first detected. These last three pieces of data may facilitate analysis of a) error associated with estimating distances to unseen birds, b) estimation of the density of singing males, rather than all birds pooled, or c) modeling of separate detection probabilities for birds inside and beyond the meadow edge. Only adult birds will be recorded on the point count data form, and observers will note whether a particular individual has already been detected from a previous point. The form will also provide a separate field for tallying ‘flyovers’, birds that fly above the top of the vegetation canopy, never touch down in the observer’s field of view, and do not appear to be foraging, displaying, or behaving in any other way that might suggest a link to the habitat below them.

Area searches (Siegel et al. 2003) will be conducted in conjunction with point counts to identify species that may be present, but were missed during the point counts. Although area searches provide an excellent way of recording as many species as possible, they are usually unsuitable for producing quantitative density estimates; this is why both methods will be utilized in this project. Area searches will be conducted after point counts have been completed, except possibly in the largest meadows, where one observer may be able to conduct the area search concurrently without affecting the other observer’s point count results. Ten minutes of area search will be allotted for every point count conducted, with a cap of 90 minutes (i.e., a meadow which is large enough to contain six point count stations is surveyed with a 60 minute area search). Area searches will be conducted by “birding,” i.e., slowly walking throughout the meadow and counting all birds detected. The observer should pay particular attention to “birdy” areas, but also be careful to cover all areas of the meadow thoroughly. Observers will not venture far into the forest beyond the meadow edge, but will record birds that were heard from the surrounding forest.

In addition to the area search, observers will keep a list of all bird species encountered at each meadow (i.e., while conducting vegetation surveys, setting up camp, etc.).

Crew members will also perform a rapid habitat assessment of the overall meadow, and possibly collect more specific data at the individual survey points. Specific vegetation data collection procedures will need to be developed in collaboration with SIEN plant biologists.

After completing their fieldwork each day, partners review each other’s data forms for missing or incorrectly recorded data, and discuss any interesting or surprising bird detections.

d) End-of-season procedures

At the end of the season the field crew leader should prepare a brief (generally not more than three pages) field season report that:

-clearly enumerates which meadows were visited during the season,
-describes any logistic difficulties that arose, and explains how they were addressed,
-clearly documents and explains any diversions form established protocols,
-points out any interesting or potentially important observations about the parks' bird communities that may have been noted during the field season (e.g. apparent changes in phenology from previous years, or notable changes in apparent abundance of particular species), and
-provides suggestions for improving the training session or field season logistics in the future.

Crew leader reports will be archived so that they are available to future crew leaders and to data analysts.

5.4) Data analysis and reporting

<u>a) Overview of database design</u>

Project databases will be formatted in Microsoft Access and will conform to Network standards. To ensure this conformity, the databases will be developed in collaboration with Network data managers.

<u>b) Data entry, verification, and editing</u>

After each week collecting data in the field, crew members will enter their data into Microsoft Access databases. At the end of the field season the project lead will be responsible for verifying, correcting, and certifying the databases.

<u>c) Reporting schedule and recommendations for routine data summaries and statistical analyses</u>

We recommend that a summary report be produced annually, with a more in-depth report assessing population trends produced every four years. The annual report should tabulate the number of detections of each species at each meadow, and also list species at each meadow that may have been detected during the area search but missed during point counts. The annual report should also model detectability as a function of distance (or use previously modeled parameters) to produce an adjusted, or absolute, density estimate for each species detected at each meadow--including both meadow-inhabiting species and forest-edge species.

At least every four years, a more in-depth analysis and report should assess temporal trends in the density estimates as well as possible distributional changes in meadow birds. The analysis should also utilize appropriate weighting procedures to assess park-wide and network-wide trends for each species. Additionally, trends at the deliberately selected 'high-priority' meadows should be analyzed separately from the rest of the data.

Finally, the four-year report should also try to place network results within the larger context of bird population changes throughout the Sierra, as measured by regional efforts such as the BBS or MAPS. The report should evaluate operational aspects of the monitoring program, such as whether any meadows need to be eliminated from the sampling regime due to access problems, whether the sampling period remains appropriate (the optimal sampling season could conceivably change over time in response to climate change), etc.

d) Data archival procedures

Data management and archival procedures will adhere to Network standards. Raw data forms will be archived at the end of the field season, if not sooner. Crew members will enter their data as the season progresses. At the end of the field season the project lead will verify, correct, and certify the databases, which will then be archived.

5.5) Personnel requirements and training

a) Roles and responsibilities

This protocol narrative assumes that a 4-person crew (two observers at YOSE and two observers at SEKI) will be available to conduct fieldwork throughout May, June, and most of July. The SIEN landbird monitoring crew will be led by a single crew leader who will be principally responsible for training and testing the crew, providing quality assurance and trouble-shooting logistic problems throughout the field season, preparing the end-of-season field report, and collecting data along with the other three crew members.

b) Qualifications

The crew leader each year must be a highly skilled birder with experience conducting VCP point counts and familiarity with Sierra Nevada birds and plant communities. Familiarity with one or more of the SIEN parks is also desirable. Ideally, the crew leader will have supervised field crews before and/or previously served as an SIEN landbird monitoring crew member. Finally s/he must be very physically fit and prepared to spend extended periods of time in the backcountry.

The other crew members should have prior birding experience, including substantial experience with Sierra birds or a demonstrated ability to quickly learn the songs and calls of new bird species. They must also be very physically fit and prepared to spend extended periods of time in the backcountry. Substantial backpacking experience and experience conducting VCP point counts are also desirable.

c) Training procedures

A comprehensive and well-designed training program is critical to the success of this project, as it will maximize observer consistency--both within and between years. Past experience has shown us that particularly experienced or talented crew members can be adequately trained in two weeks or less, but we recommend allowing up to three weeks for the training period, to maximize the likelihood that all observers will be qualified to conduct point counts at the end of the training session. The training session should provide instruction in the following topics:

-bird identification by sight and sound
-conducting point counts
-estimating distance to birds
-plant identification and habitat assessment
-completing field forms
-orienteering
-first aid and backcountry safety

At the end of the training session, all observers must pass a rigorous bird identification exam, which certifies that they can competently identify by sight and sound all species they are expected to encounter during the field season.

5.6) Costs and Operational requirements

a) Annual workload and field schedule

Crew training should begin between April 25 and May 1 each year, depending on the experience level of the crew. Meadow surveys should begin around May 15. The sampling design assumes that in each park, two observers will work together to survey six groups of up to six meadows per group. Each group of meadows requires two observers seven or eight days to survey. We recommend providing observers with three days off after surveying each group. Sampling will begin with the lowest-elevation group of meadows in each park, and observers will gradually progress upslope throughout the season. The last meadow should be surveyed by July 22.

b) Facility and equipment needs

This project requires minimal special facilities and equipment. The crew will require housing in the vicinity of both large parks for the duration of the season. Necessary equipment includes backpacking gear and binoculars (which crew members should provide for themselves), as well as GPS units, radios, water filters and miscellaneous smaller items. Computer access is necessary during the training session, and throughout the season if crew members are to enter their own data. One or more laser rangefinders may be helpful during training, but is not strictly necessary.

c) Startup costs and budget considerations

This project will incur fairly minimal startup costs beyond the present contract, which funds the development of this protocol narrative, as well as the production a spatially explicit sampling design for each park. If the project is selected, more detailed Standard Operating Procedures (Oakley et al. 2003) will likely be required, but this should not be a large expense.

If the Network decides to contract the survey work out to an external cooperator, then no additional personnel should need to be hired. The estimated annual cost (in 2005 dollars--not accounting for salary increases or inflation between now and the onset of the program) for The Institute for Bird Populations to prepare for a field season, deploy a four-person crew (two people in each large park), to survey meadows from late May through late July, enter the data into electronic databases, analyze data and produce an annual report is approximately $67,000.

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Table 1. Proposed panel design for landscape-level landbird monitoring at each of the large parks in the SIEN. Panel 1 includes 18 transects that will be sampled annually, whereas the other 4 panels each contain 18 transects that will be surveyed every four years, on a rotating schedule.

	No. of Transects Surveyed							
Panel	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8
1	18	18	18	18	18	18	18	18
2	18				18			
3		18				18		
4			18				18	
5				18				18

Table 2. Estimated number of years of consecutive monitoring required to yield an 80% chance of detecting a 4% annual population decrease at SEKI, at significance level (alpha) = 0.2. Estimates were produced using the TRENDS software package, and rely on predicted coefficients of variation (‘Expected CV’) for density that were derived from the CVs obtained from the avian inventory project at SEKI (‘Pilot Study CV’).

Species	Pilot Study CV	Expected CV	Years of Monitoring Needed to Reach (1-beta) = 0.8
Mountain Quail	0.176	0.327	17
Hairy Woodpecker	0.205	0.380	19
White-headed Woodpecker	0.218	0.404	20
Northern Flicker	0.435	0.806	30
Olive-sided Flycatcher	0.299	0.555	25
Western Wood-Pewee	0.086	0.160	11
Dusky Flycatcher	0.305	0.566	25
Warbling Vireo	0.423	0.784	30
Steller’s Jay	0.096	0.177	12
Clark’s Nutcracker	0.100	0.186	12
Common Raven	0.197	0.364	19
Mountain Chickadee	0.073	0.135	10
Red-breasted Nuthatch	0.770	1.427	39
White-breasted Nuthatch	0.172	0.319	17
Brown Creeper	0.431	0.798	30
Rock Wren	0.237	0.440	21
Winter Wren	0.231	0.429	21
Golden-crowned Kinglet	0.274	0.509	23
Ruby-crowned Kinglet	0.183	0.339	18
Townsend’s Solitaire	0.144	0.267	15
Hermit Thrush	0.241	0.447	21
American Robin	0.208	0.386	20
Wrentit	0.185	0.343	18
American Pipit	0.282	0.522	24
Nashville Warbler	0.354	0.657	27
Yellow-rumped Warbler	0.209	0.388	20
Hermit Warbler	0.414	0.768	30
MacGillivray’s Warbler	0.478	0.885	32
Wilson’s Warbler	0.169	0.314	17
Western Tanager	0.109	0.203	13
Green-tailed Towhee	0.506	0.938	33
Spotted Towhee	0.396	0.734	29
Chipping Sparrow	0.277	0.514	24
Fox Sparrow	0.316	0.586	25
Lincoln’s Sparrow	0.232	0.429	21
White-crowned Sparrow	0.107	0.198	13
Dark-eyed Junco	0.075	0.138	10
Black-headed Grosbeak	0.124	0.230	14

Table 2, continued

Species	Pilot Study CV	Expected CV	Years of Monitoring Needed to Reach (1-beta) = 0.8
Lazuli Bunting	0.215	0.399	20
Gray-crowned Rosy-Finch	0.236	0.438	21
Cassin’s Finch	0.322	0.597	26
Pine Siskin	0.181	0.336	18
Evening Grosbeak	0.214	0.396	20

Table 3. Species-specific logarithmic function constants (y_0 and a), expected proportion of monitoring transects with detections, and expected number of monitoring transects (out of 90 total) with detections at SEKI.

Species	y_0	a	Expected Proportion of Monitoring Transects	Expected No. of Monitoring Transects
Blue Grouse	0.017	0.037	0.113	10
Mountain Quail	0.109	0.099	0.371	33
California Quail	0.015	0.005	0.029	3
Spotted Sandpiper	0.013	0.022	0.071	6
Mourning Dove	-0.002	0.012	0.030	3
White-throated Swift	-0.004	0.022	0.055	5
Anna's Hummingbird	-0.014	0.037	0.084	8
Calliope Hummingbird	0.006	0.018	0.053	5
Rufous Hummingbird	0.009	0.068	0.190	17
Acorn Woodpecker	0.019	0.006	0.034	3
Williamson's Sapsucker	0.015	0.057	0.164	15
Red-breasted Sapsucker	0.015	0.026	0.082	7
Hairy Woodpecker	0.054	0.081	0.269	24
White-headed Woodpecker	0.027	0.087	0.256	23
Northern Flicker	0.081	0.141	0.454	41
Pileated Woodpecker	0.002	0.021	0.058	5
Olive-sided Flycatcher	0.111	0.122	0.433	39
Western Wood-Pewee	0.095	0.119	0.409	37
Hammond's Flycatcher	0.027	0.036	0.121	11
Dusky Flycatcher	0.264	0.238	0.892	80
Pacific-slope Flycatcher	0.008	0.037	0.104	9
Ash-throated Flycatcher	0.033	0.010	0.058	5
Cassin's Vireo	0.007	0.061	0.168	15
Hutton's Vireo	0.001	0.027	0.071	6
Warbling Vireo	0.101	0.135	0.457	41
Steller's Jay	0.180	0.200	0.706	64
Western Scrub-Jay	0.015	0.021	0.071	6
Clark's Nutcracker	0.118	0.144	0.497	45
Common Raven	0.006	0.072	0.196	18
Mountain Chickadee	0.558	0.160	0.981	88
Oak Titmouse	-0.002	0.019	0.049	4
Bushtit	0.001	0.008	0.022	2
Red-breasted Nuthatch	0.202	0.139	0.568	51
White-breasted Nuthatch	0.033	0.097	0.290	26
Brown Creeper	0.160	0.174	0.620	56
Rock Wren	0.007	0.068	0.186	17
Bewick's Wren	0.017	0.015	0.058	5
House Wren	0.022	0.025	0.087	8

Table 3, continued

Species	y_0	a	Expected Proportion of Monitoring Transects	Expected No. of Monitoring Transects
Winter Wren	0.046	0.045	0.166	15
American Dipper	0.006	0.009	0.029	3
Golden-crowned Kinglet	0.284	0.088	0.515	46
Ruby-crowned Kinglet	0.053	0.069	0.235	21
Blue-gray Gnatcatcher	0.031	0.008	0.051	5
Mountain Bluebird	-0.002	0.039	0.100	9
Townsend's Solitaire	0.052	0.137	0.414	37
Hermit Thrush	0.278	0.134	0.631	57
American Robin	0.271	0.183	0.752	68
Wrentit	0.053	0.014	0.090	8
American Pipit	0.002	0.019	0.052	5
Orange-crowned Warbler	0.004	0.019	0.053	5
Nashville Warbler	0.085	0.087	0.314	28
Yellow Warbler	0.000	0.018	0.046	4
Yellow-rumped Warbler	0.420	0.210	0.974	88
Black-throated Gray Warbler	0.010	0.025	0.076	7
Hermit Warbler	0.064	0.058	0.218	20
MacGillivray's Warbler	0.098	0.123	0.423	38
Wilson's Warbler	0.049	0.083	0.268	24
Western Tanager	0.236	0.091	0.477	43
Green-tailed Towhee	0.076	0.045	0.195	18
Spotted Towhee	0.086	0.041	0.194	17
California Towhee	0.018	0.012	0.050	4
Chipping Sparrow	0.034	0.049	0.163	15
Fox Sparrow	0.171	0.103	0.442	40
Song Sparrow	0.009	0.017	0.054	5
Lincoln's Sparrow	0.054	0.031	0.135	12
White-crowned Sparrow	0.115	0.063	0.281	25
Dark-eyed Junco	0.565	0.181	1.000	90
Black-headed Grosbeak	0.059	0.039	0.162	15
Lazuli Bunting	0.029	0.027	0.099	9
Brewer's Blackbird	0.003	0.017	0.047	4
Brown-headed Cowbird	0.005	0.033	0.092	8
Gray-crowned Rosy-Finch	0.049	0.020	0.102	9
Pine Grosbeak	-0.003	0.019	0.048	4
Purple Finch	0.007	0.060	0.165	15
Cassin's Finch	0.127	0.153	0.530	48
Red Crossbill	0.021	0.041	0.130	12
Pine Siskin	0.037	0.094	0.284	26
Lesser Goldfinch	0.011	0.034	0.101	9
Evening Grosbeak	0.027	0.059	0.182	16

Table 4. Sierra Nevada Breeding Bird Survey (BBS) routes visited for on-the-ground vegetation classification.

BBS Route No.	BBS Route Name
14-013	Westville[1]
14-018	Dardanelle
14-022	Bass Lake
14-055	Lake Success
14-078	Johnsonville
14-095	Lumberyard
14-110	Greenhorn Mountain
14-128	Kelso Valley
14-156	Tuolumne Grove
14-158	Sattley
14-181	Genessee
14-185	Downieville
14-188	Riverton
14-205	Lakeshore
14-415	Paxton
14-416	Meadow Valley
14-417	Little Truckee
14-419	Pollock Pines
14-420	Placerville
14-421	Coulterville
14-422	Wawona
14-423	Pine Mountain
14-424	Kernville
14-425	South Lake
14-433	Chilcoot
14-434	Strawberry
14-436	Last Chance
14-418	Foresthill

[1]Poor stop descriptions; could not definitively locate 14 points.

Table 5. Representation of CWHR habitats across the Sierra and across Sierra BBS points that we visited. Bold type indicates habitats that are under-sampled relative to their aerial extent in the Sierra Nevada. Italic type indicates habitats represented by fewer than 20 points.

CWHR Habitat	Area (ha) in the Sierra Nevada[1]	Percent of the Sierra Nevada[1]	No. of BBS Points[2]	Percent of BBS Points	Percent of Sierra Nevada minus Percent of BBS Points
Sierra Mixed Conifer	1,002,929	11.76	512	36.94	-25.52
Annual Grassland	750,952	8.81	23	1.66	7.15
Ponderosa Pine	712,167	8.35	112	8.08	0.27
Blue Oak Woodland	**571,532**	**6.70**	**37**	**2.67**	**4.03**
Blue Oak-Digger Pine	528,708	6.20	104	7.50	-1.30
Jeffrey Pine	511,548	6.00	216	15.58	-9.58
Red Fir	458,345	5.38	39	2.81	2.57
Barren	***400,502***	***4.70***	***5***	***0.36***	***4.34***
Irrigated Hayfield	***398,338***	***4.67***	***0***	***0***	***4.67***
Montane Hardwood	389,606	4.57	67	4.83	-0.26
Desert Scrub	***354,341***	***4.16***	***6***	***0.43***	***3.73***
Cropland	***325,605***	***3.82***	***1***	***0.07***	***3.75***
Subalpine Conifer	***290,830***	***3.41***	***3***	***0.22***	***3.19***
Sagebrush	268,557	3.15	27	1.95	1.20
Pinyon-Juniper	205,119	2.41	20	1.44	0.97
Lodgepole Pine	179,479	2.11	34	2.45	-0.34
Orchard-Vineyard	*173,325*	*2.03*	*3*	*0.22*	*1.81*
Montane Chaparral	153,784	1.80	28	2.02	-0.22
White Fir	121,215	1.42	75	5.41	-3.99
Mixed Chaparral	*117,038*	*1.37*	*7*	*0.51*	*0.86*
Lacustrine	105,869	1.24	20	1.44	-0.20
Urban	99,953	1.17	15	1.08	0.09
Chamise-Redshank Chaparral	*92,515*	*1.09*	*8*	*0.58*	*0.51*
Pasture	60,201	0.71	71	5.12	-4.41
Alpine Dwarf-Shrub	*50,422*	*0.59*	*2*	*0.14*	*0.45*

Table 5, continued

CWHR Habitat	Area (ha) in the Sierra Nevada[1]	Percent of the Sierra Nevada[1]	No. of BBS Points[2]	Percent of BBS Points	Percent of Sierra Nevada minus Percent of BBS Points
Juniper	*46,447*	*0.54*	*5*	*0.36*	*0.18*
Valley Oak Woodland	*31,754*	*0.37*	*0*	*0*	*0.37*
Eastside Pine	29,259	0.34	40	2.89	-2.55
Montane Hardwood-Conifer	23,027	0.27	202	14.57	-14.30
Wet Meadow	*19,355*	*0.23*	*15*	*1.08*	*-0.85*
Low Sagebrush	15,544	0.18	31	2.24	-2.06
Montane Riparian	8,057	0.09	51	3.68	-3.59
Joshua Tree	7,303	0.09	23	1.66	-1.57
Aspen	*7,274*	*0.09*	*1*	*0.07*	*0.02*
Bitterbrush	*4,607*	*0.05*	*5*	*0.36*	*-0.31*
Valley Foothill Riparian	*4,199*	*0.05*	*0*	*0*	*0.05*
Freshwater Emergent Wetland	*3,680*	*0.04*	*4*	*0.29*	*-0.25*
Closed Cone Pine-Cypress	*1,067*	*0.01*	*0*	*0*	*0.01*
Riverine	*489*	*0.01*	*9*	*0.65*	*-0.64*
Desert Riparian	*161*	*0*	*0*	*0*	*0*
Perennial Grassland	*148*	*0*	*0*	*0*	*0*
Eucalyptus	*0*	*0*	*1*	*0.07*	*-0.07*

[1]Based on the 'Jepson' boundaries defined by Hickman (1993) and California Gap Analysis Project (1998).
[2]The number of points classified as being dominated by the indicated habitat on at least one side of the road.

Table 6. Proposed panel design for the meadow bird monitoring program at each of the large parks. Panel 1 includes 18 meadows that will be sampled annually, whereas the other four panels each contain 18 meadows that will surveyed every four years, on a rotating schedule. Depending on the results of a forthcoming GIS analysis, the number of meadows in each panel may be reduced, perhaps to 12.

	No. of Meadows Surveyed							
Panel	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8
1	18	18	18	18	18	18	18	18
2	18				18			
3		18				18		
4			18				18	
5				18				18

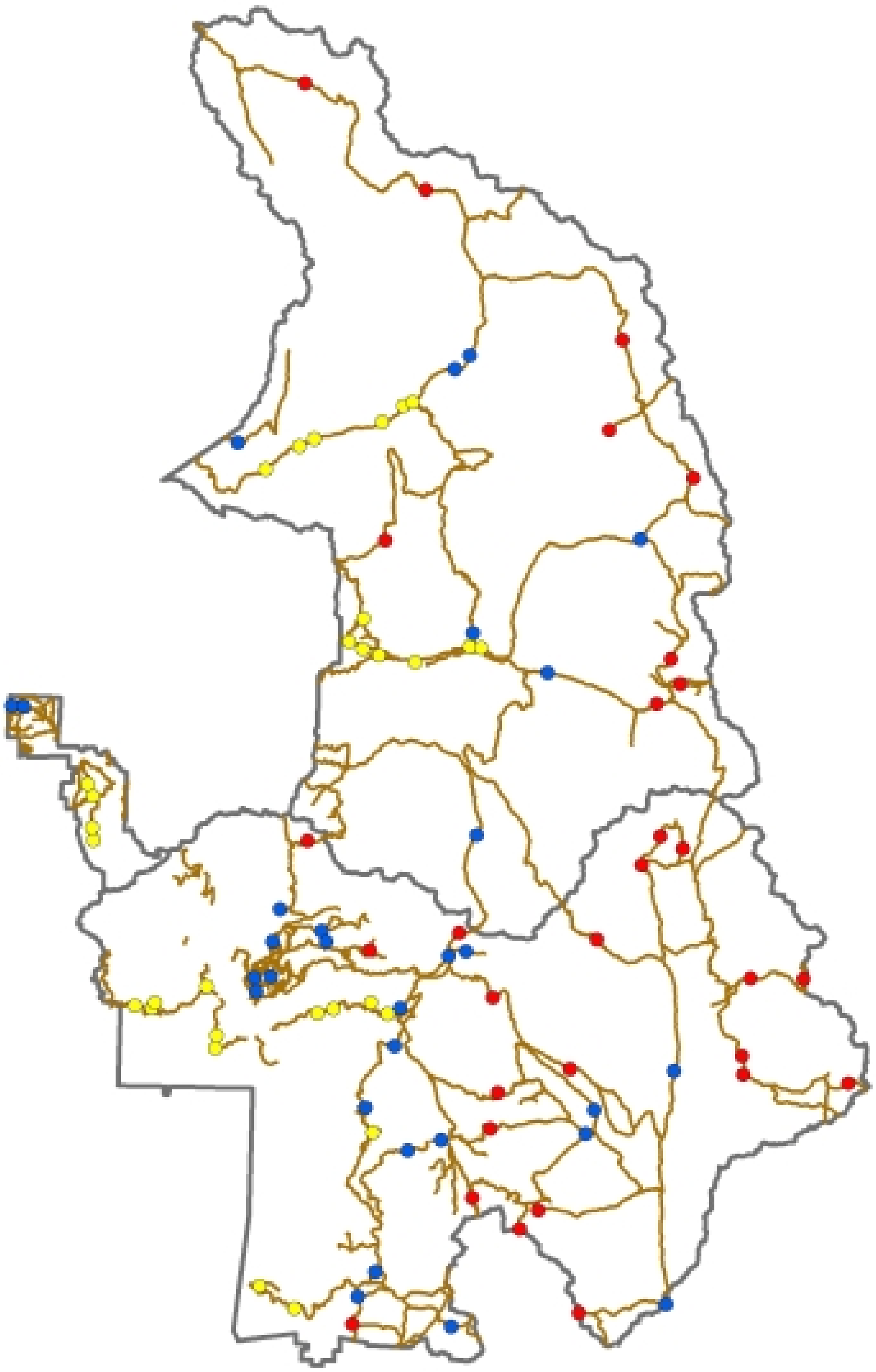


Figure 1. Transect starting points at Sequoia and Kings Canyon National Parks. Brown lines indicate trails. Yellow circles indicate low-elevation transects (<1,350 m), blue circles indicate mid-elevation transects (1,350-2,750 m), and red circles indicate high-elevation (>2750 m) transects. Starting points were selected using the Generalized Random-Tessellation Stratified (GRTS) sampling method with reverse hierarchical ordering (Stevens and Olsen 1999, 2003, 2004). Transects will start from points on trails, but then extend away from the trail perpendicularly in both directions.

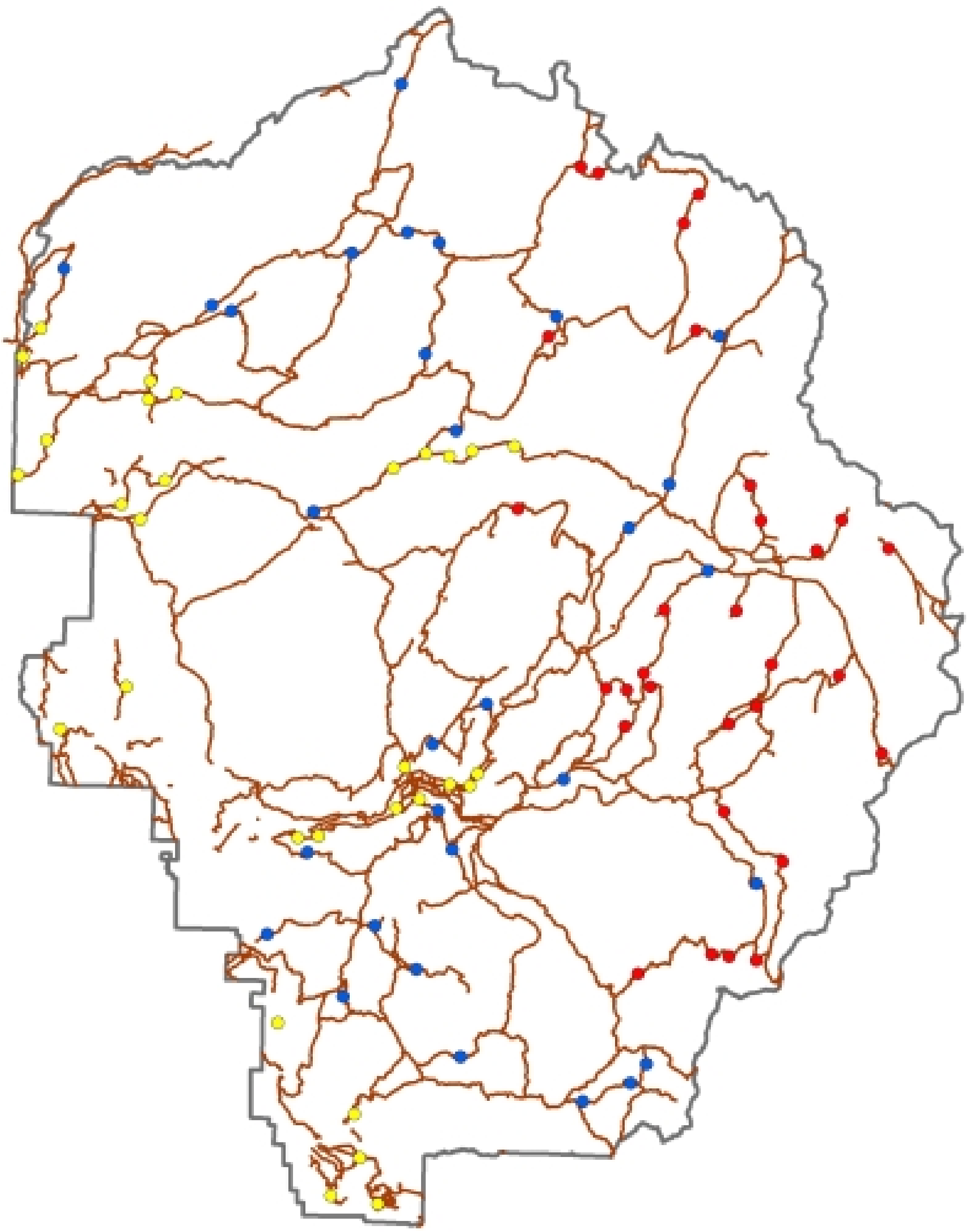


Figure 2. Transect starting points at Yosemite National Park. Brown lines indicate trails. Yellow circles indicate low-elevation transects (<1,350 m), blue circles indicate mid-elevation transects (1,350-2,750 m), and red circles indicate high-elevation (>2750 m) transects. Starting points were selected using the Generalized Random-Tessellation Stratified (GRTS) sampling method with reverse hierarchical ordering (Stevens and Olsen 1999, 2003, 2004). Transects will start from points on trails, but then extend away from the trail perpendicularly in both directions.

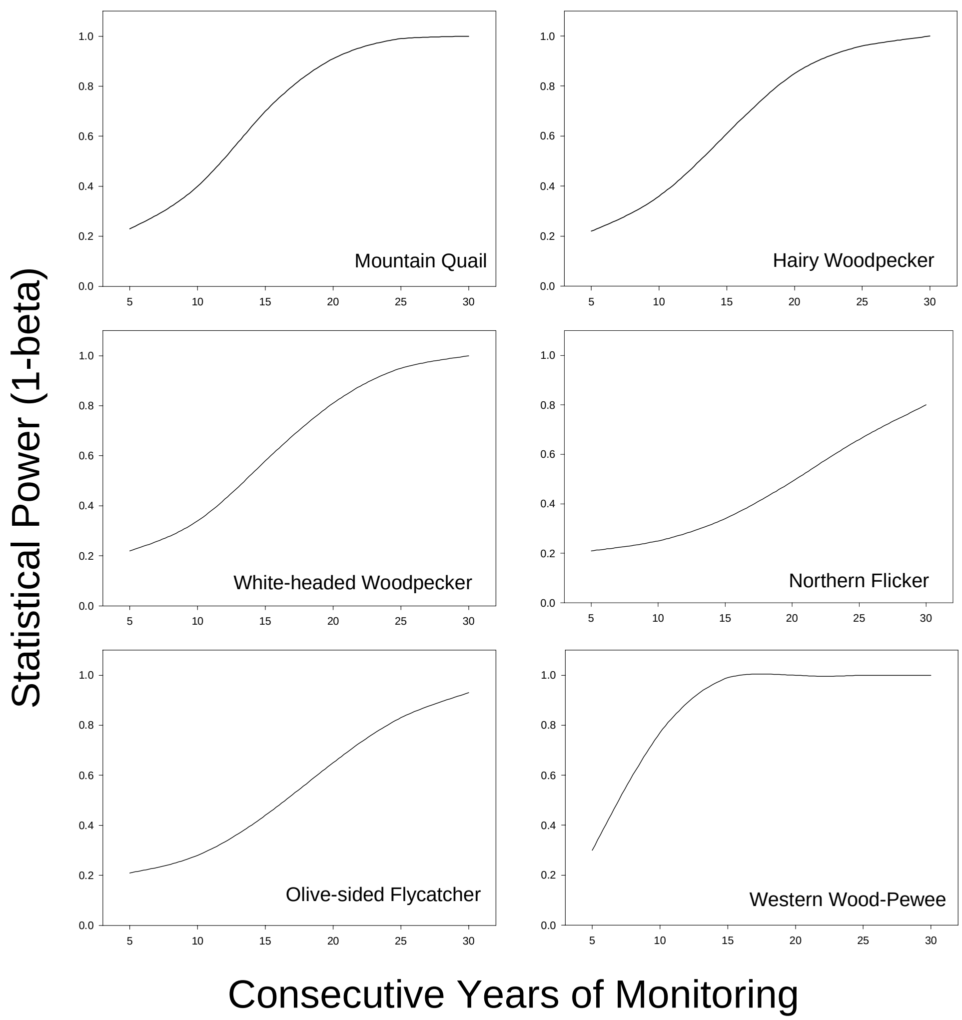


Figure 3. Relationship between number of consecutive years of monitoring and predicted statistical power for detecting a 4% annual population decrease at SEKI, at significance level (alpha) = 0.2. Figure continues on next page.

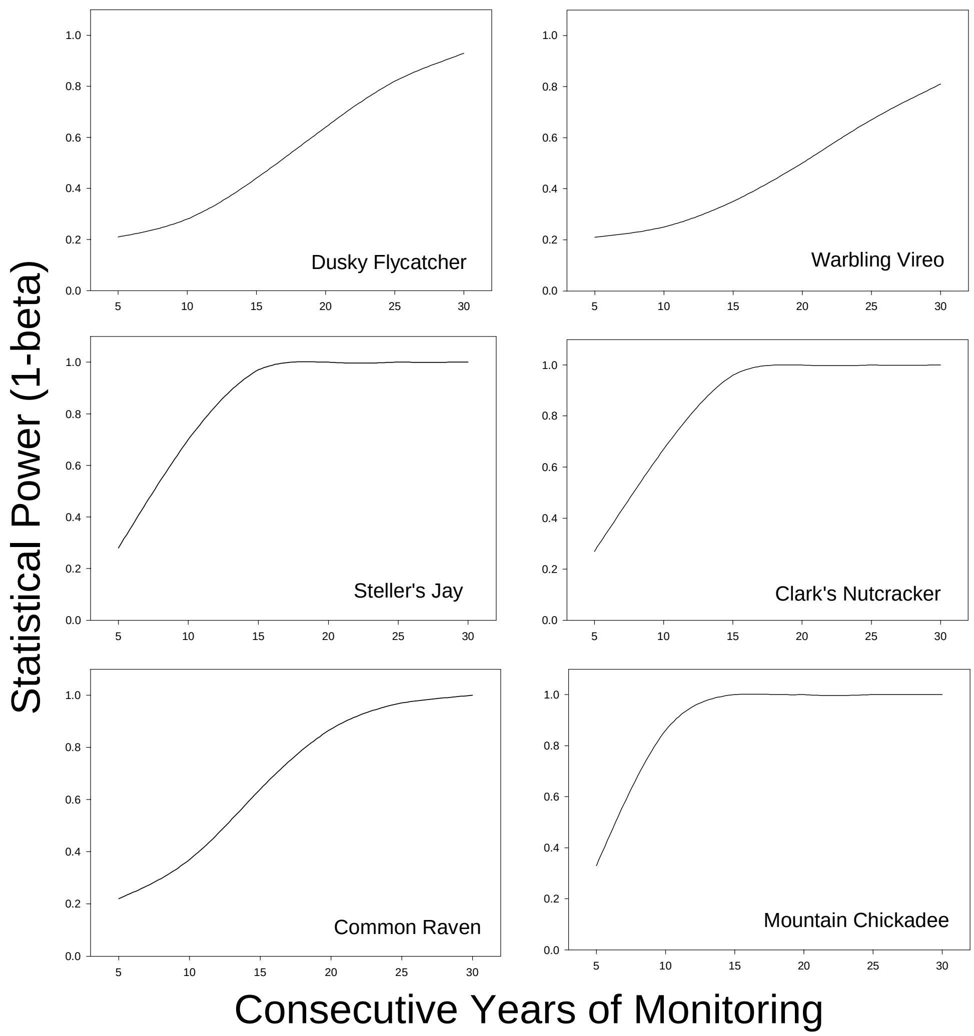


Figure 3, continued. Relationship between number of consecutive years of monitoring and predicted statistical power for detecting a 4% annual population decrease at SEKI, at significance level (alpha) = 0.2. Figure continues on next page.

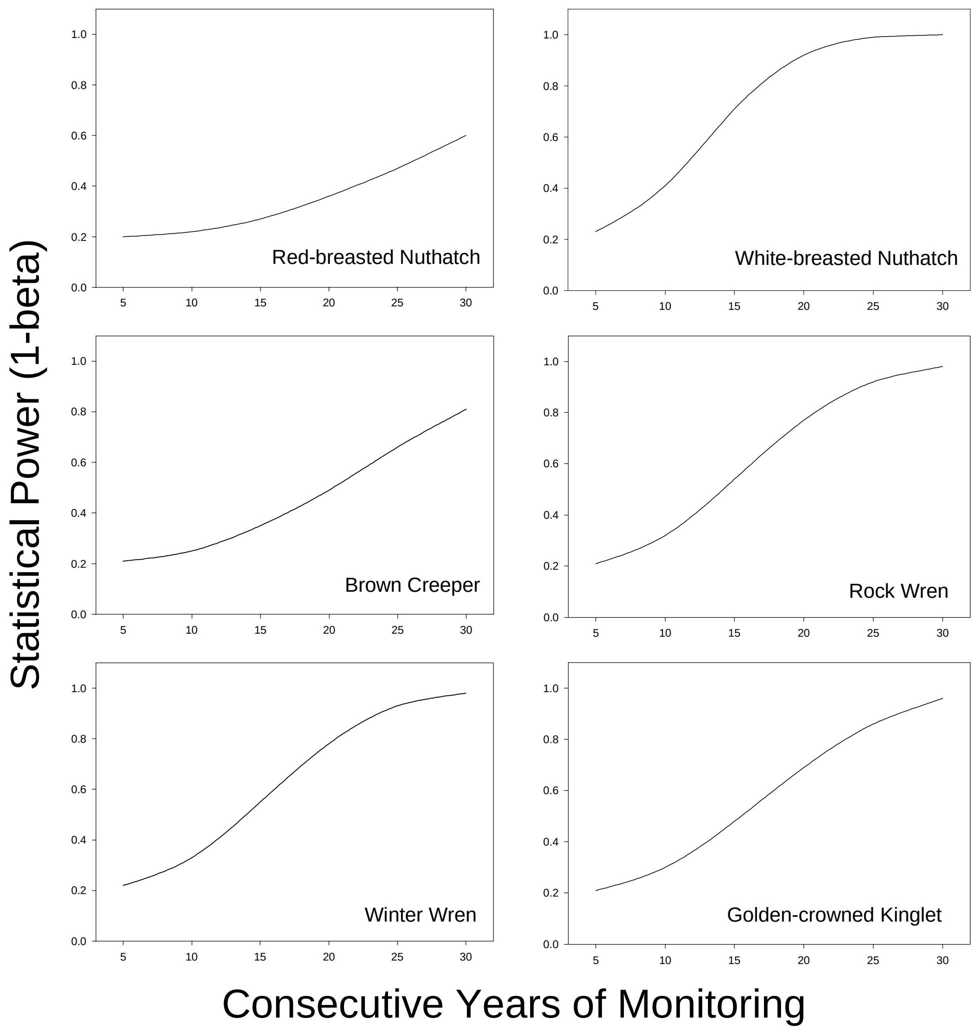


Figure 3, continued. Relationship between number of consecutive years of monitoring and predicted statistical power for detecting a 4% annual population decrease at SEKI, at significance level (alpha) = 0.2. Figure continues on next page.

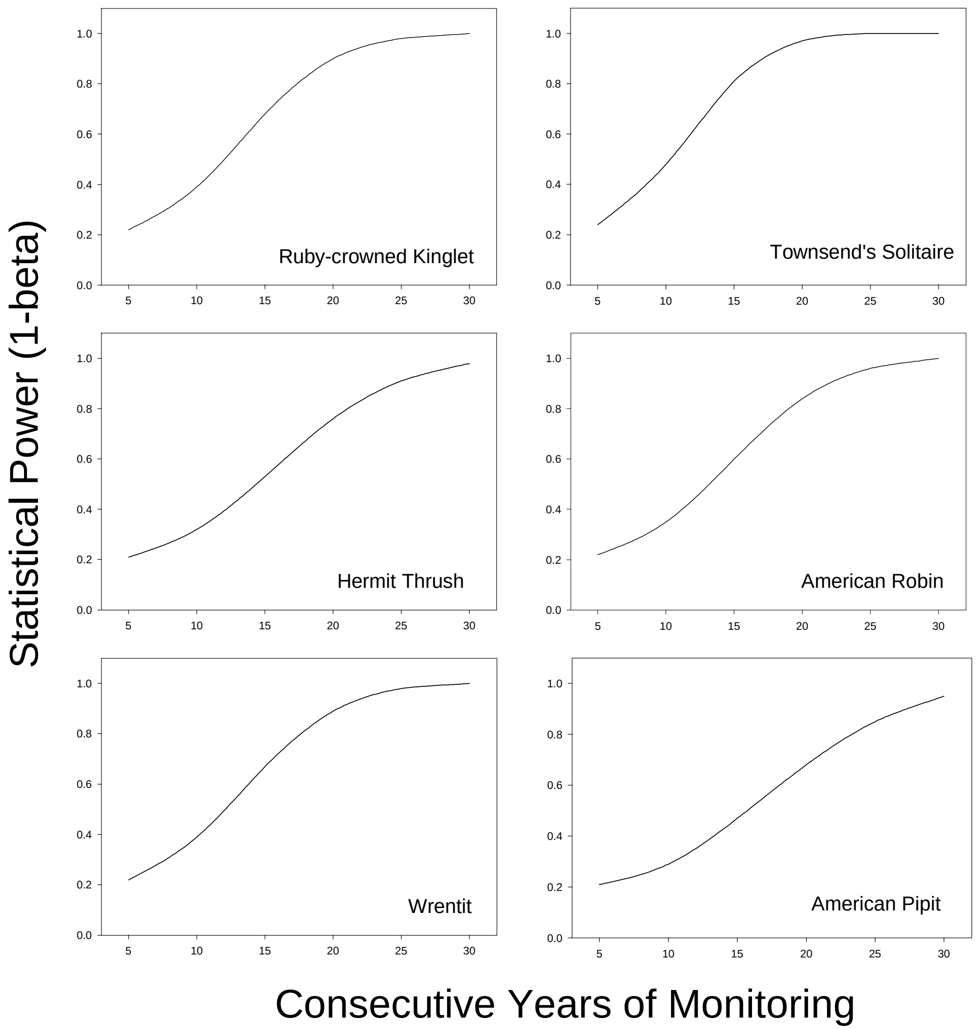


Figure 3, continued. Relationship between number of consecutive years of monitoring and predicted statistical power for detecting a 4% annual population decrease at SEKI, at significance level (alpha) = 0.2. Figure continues on next page.

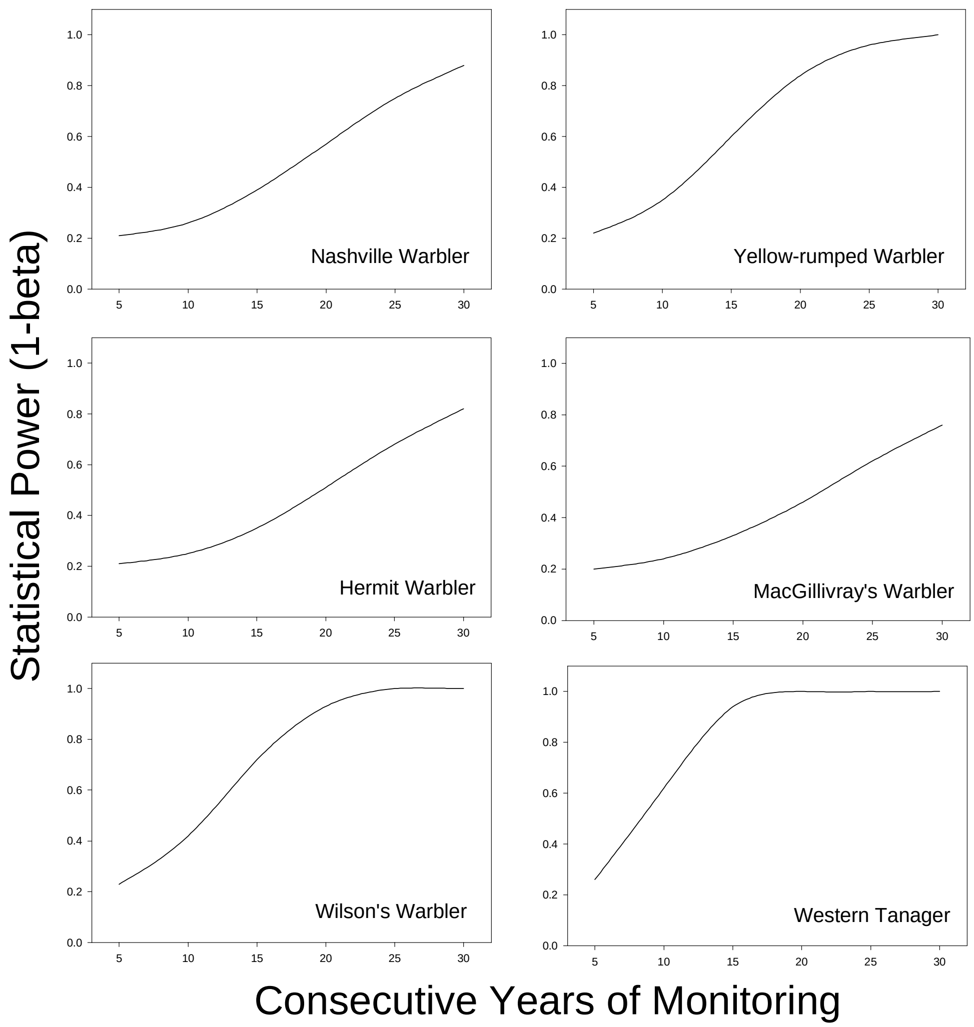


Figure 3, continued. Relationship between number of consecutive years of monitoring and predicted statistical power for detecting a 4% annual population decrease at SEKI, at significance level (alpha) = 0.2. Figure continues on next page.

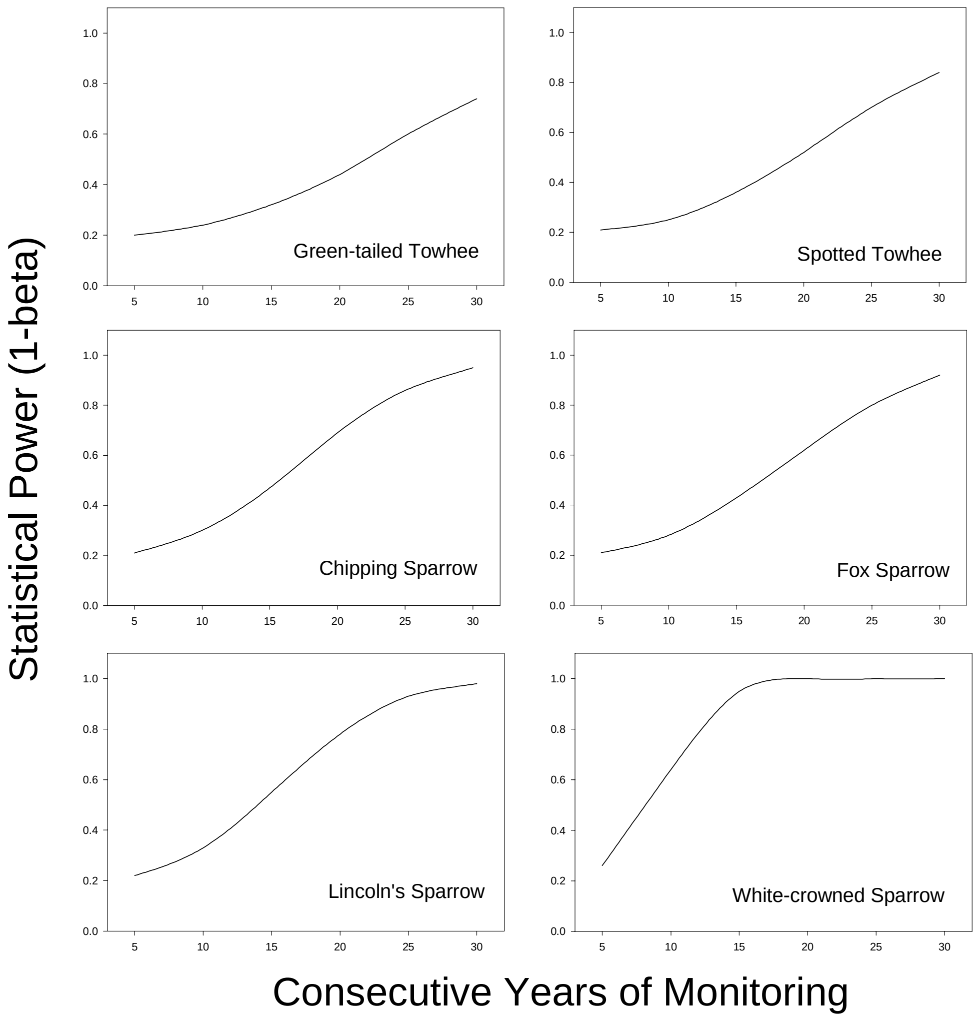


Figure 3, continued. Relationship between number of consecutive years of monitoring and predicted statistical power for detecting a 4% annual population decrease at SEKI, at significance level (alpha) = 0.2. Figure continues on next page.

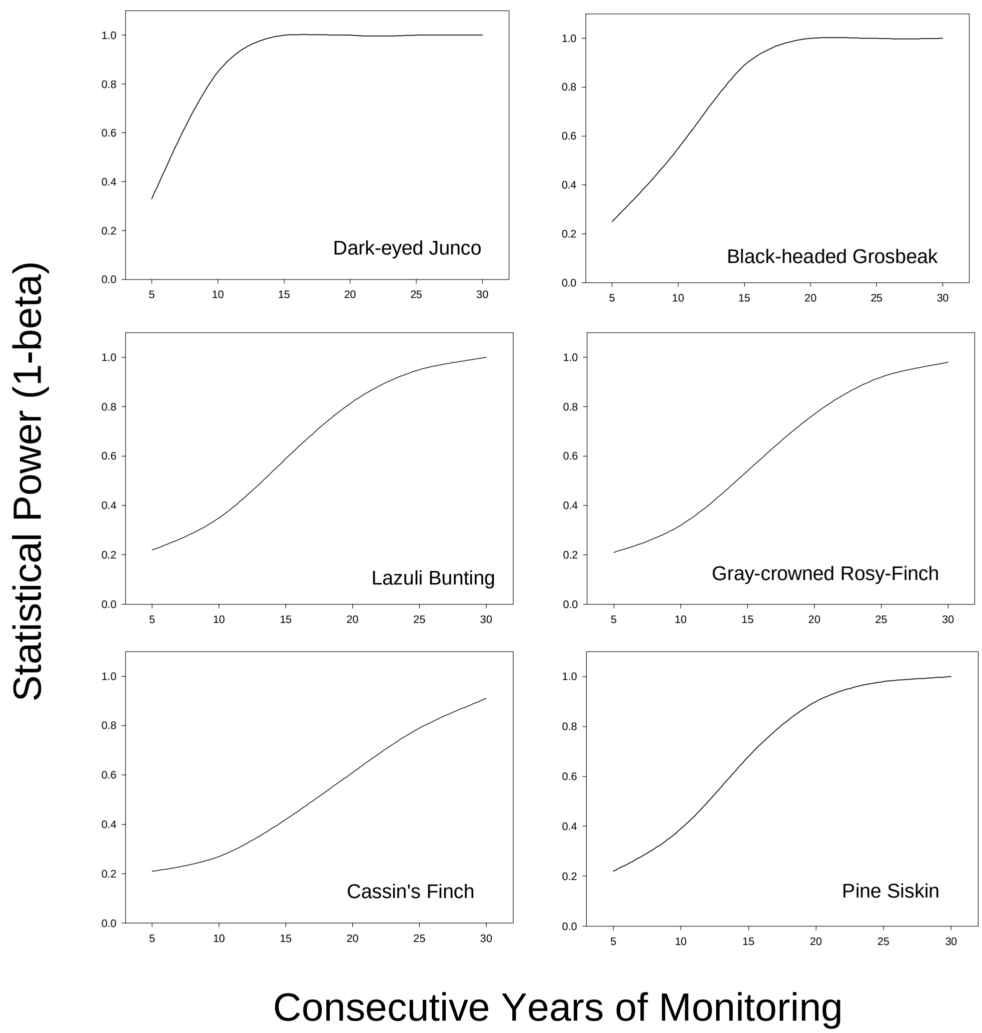


Figure 3, continued. Relationship between number of consecutive years of monitoring and predicted statistical power for detecting a 4% annual population decrease at SEKI, at significance level (alpha) = 0.2. Figure continues on next page.

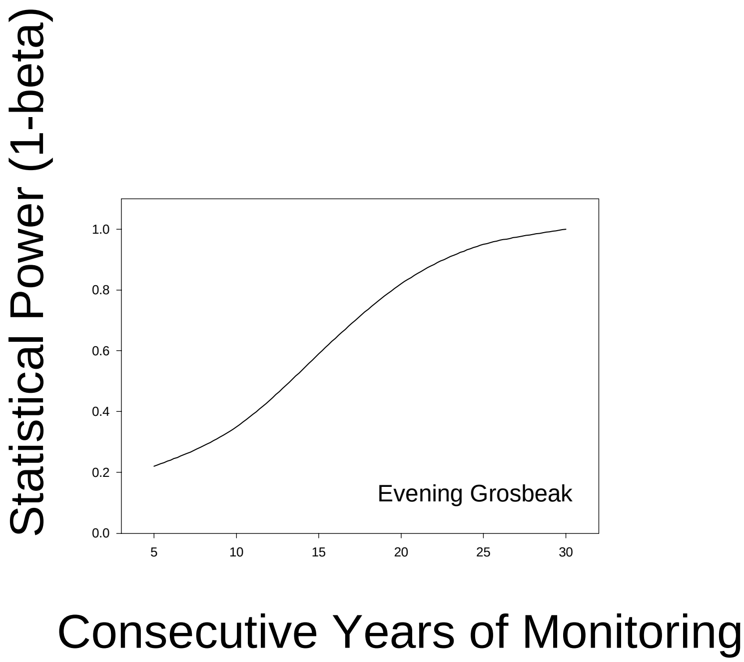


Figure 3, continued. Relationship between number of consecutive years of monitoring and predicted statistical power for detecting a 4% annual population decrease at SEKI, at significance level (alpha) = 0.2.

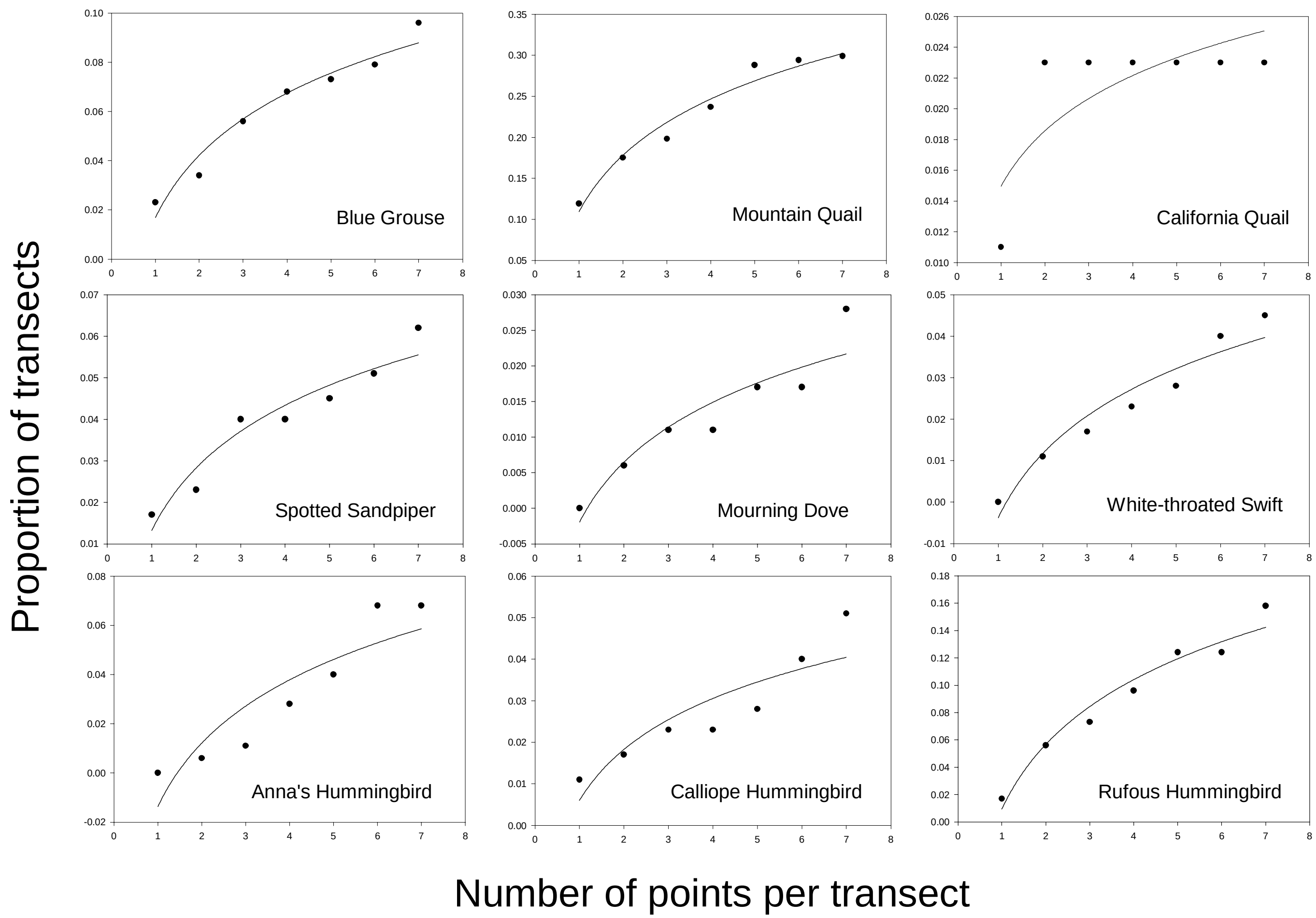


Figure 4. Relationship between number of points per inventory transect and the proportion of transects on which each species was detected. Relationships are based on the first seven points of 177 SEKI inventory transects, and are modeled as logistic functions. Figure continues on next page.

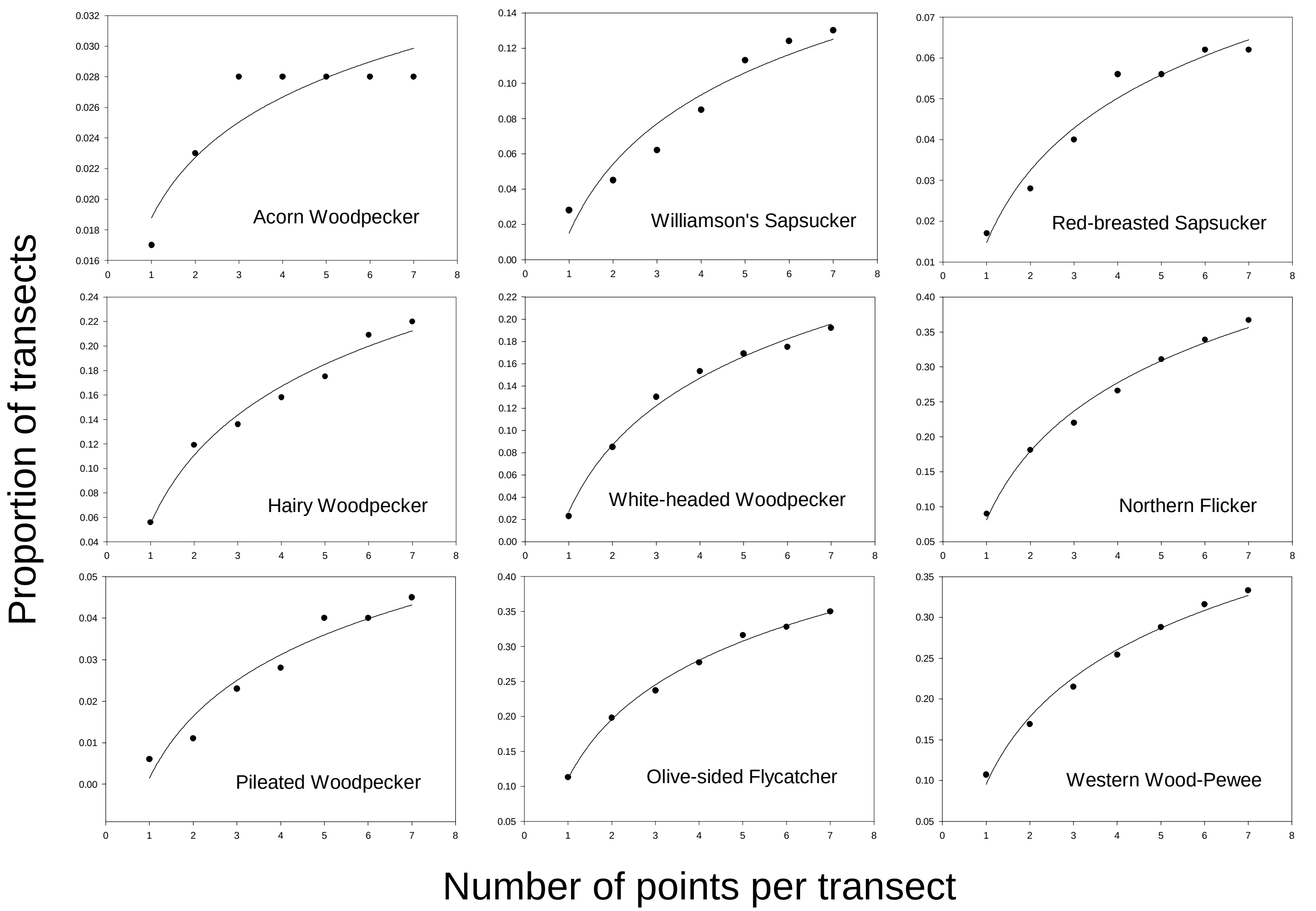


Figure 4, continued. Relationship between number of points per inventory transect and the proportion of transects on which each species was detected. Relationships are based on the first seven points of 177 SEKI inventory transects, and are modeled as logistic functions. Figure continues on next page.

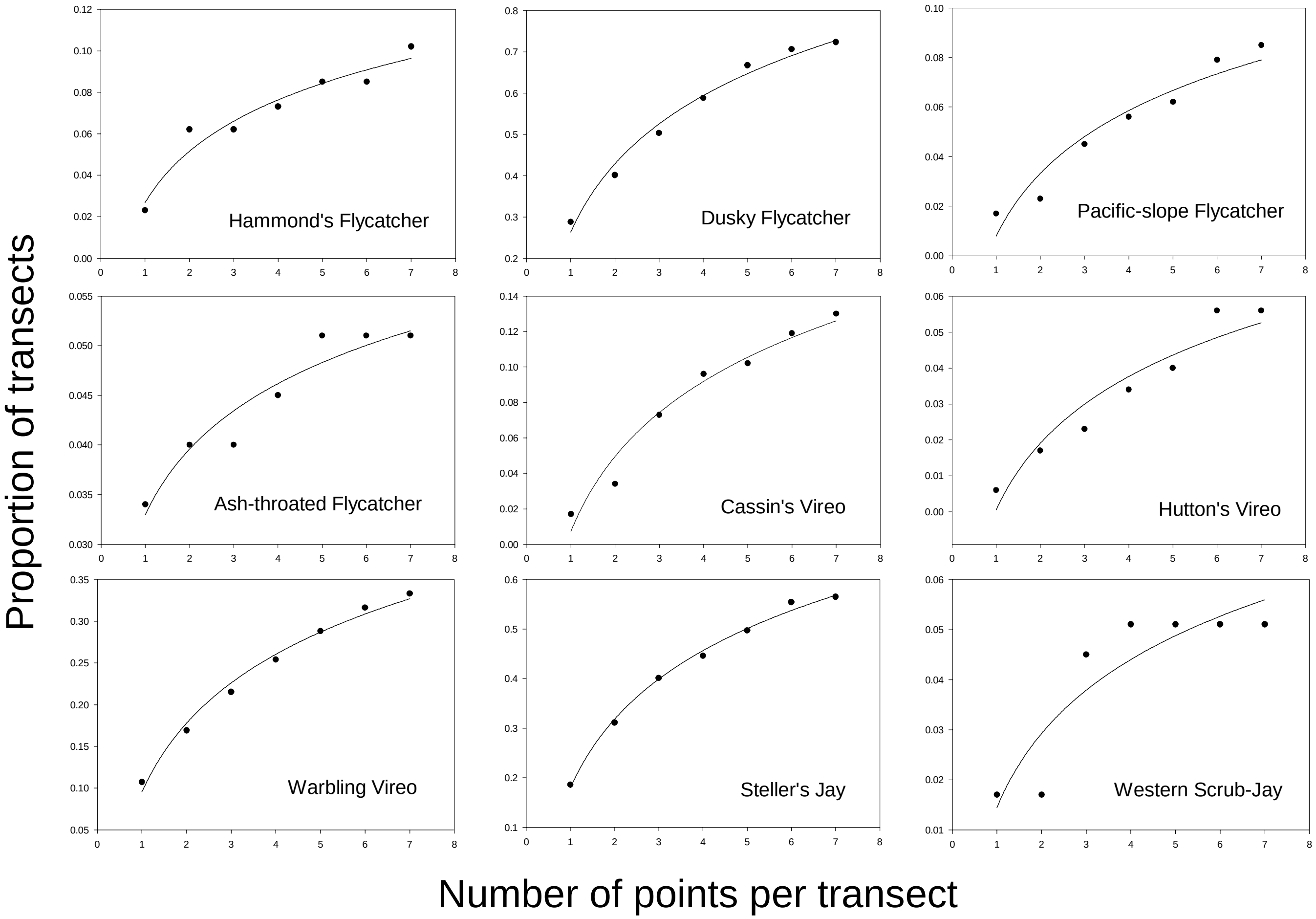


Figure 4, continued. Relationship between number of points per inventory transect and the proportion of transects on which each species was detected. Relationships are based on the first seven points of 177 SEKI inventory transects, and are modeled as logistic functions. Figure continues on next page.

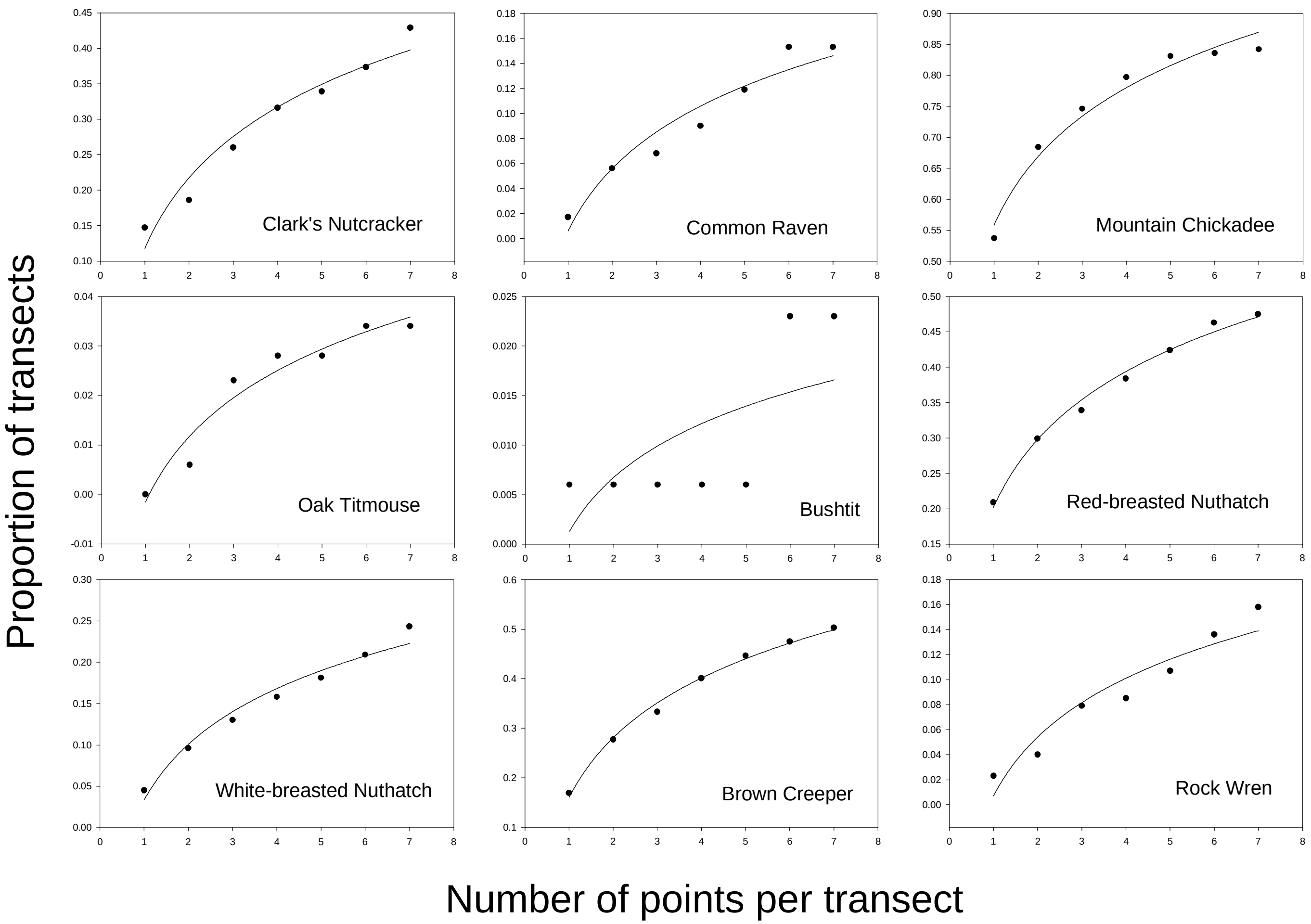


Figure 4, continued. Relationship between number of points per inventory transect and the proportion of transects on which each species was detected. Relationships are based on the first seven points of 177 SEKI inventory transects, and are modeled as logistic functions. Figure continues on next page.

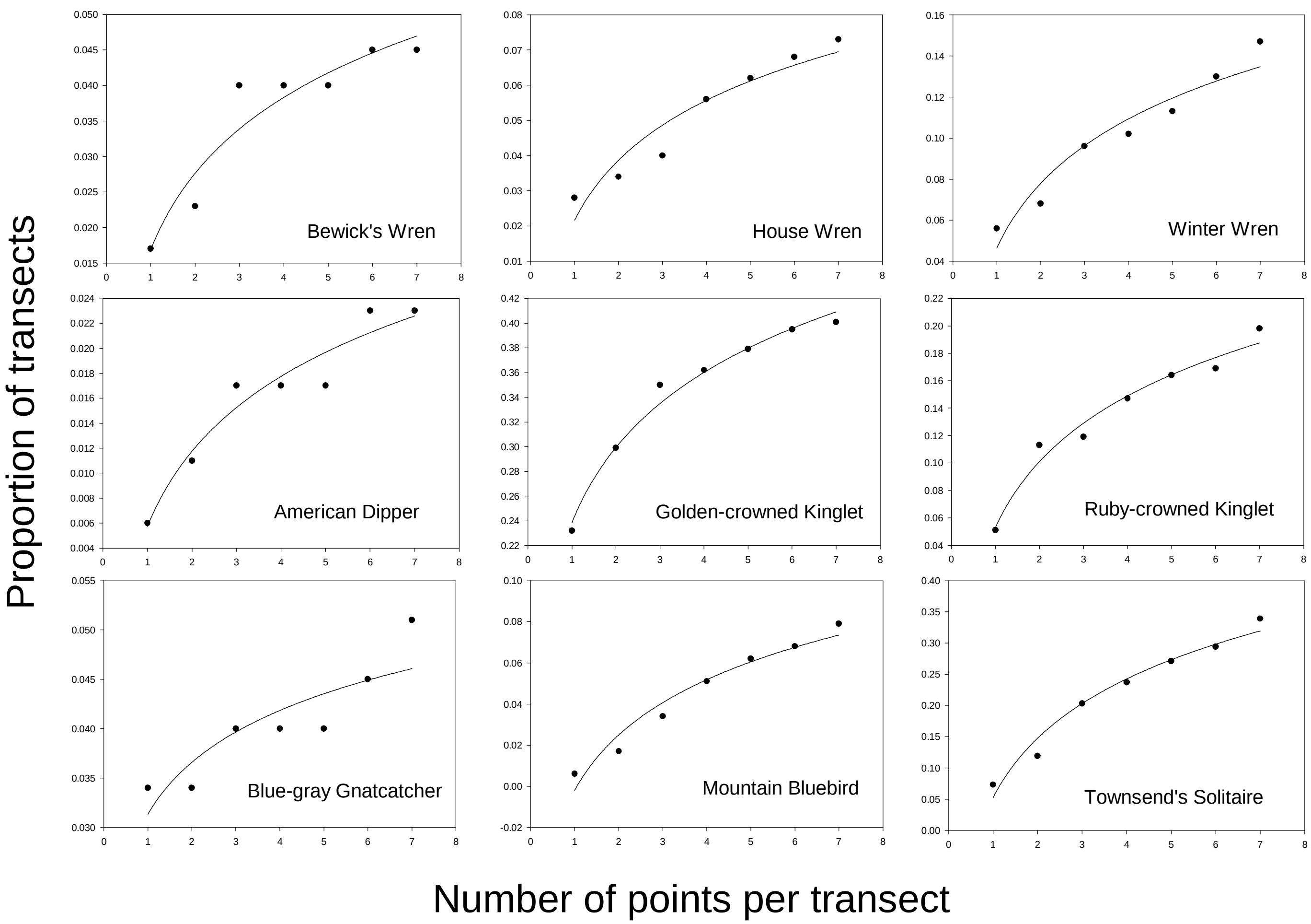
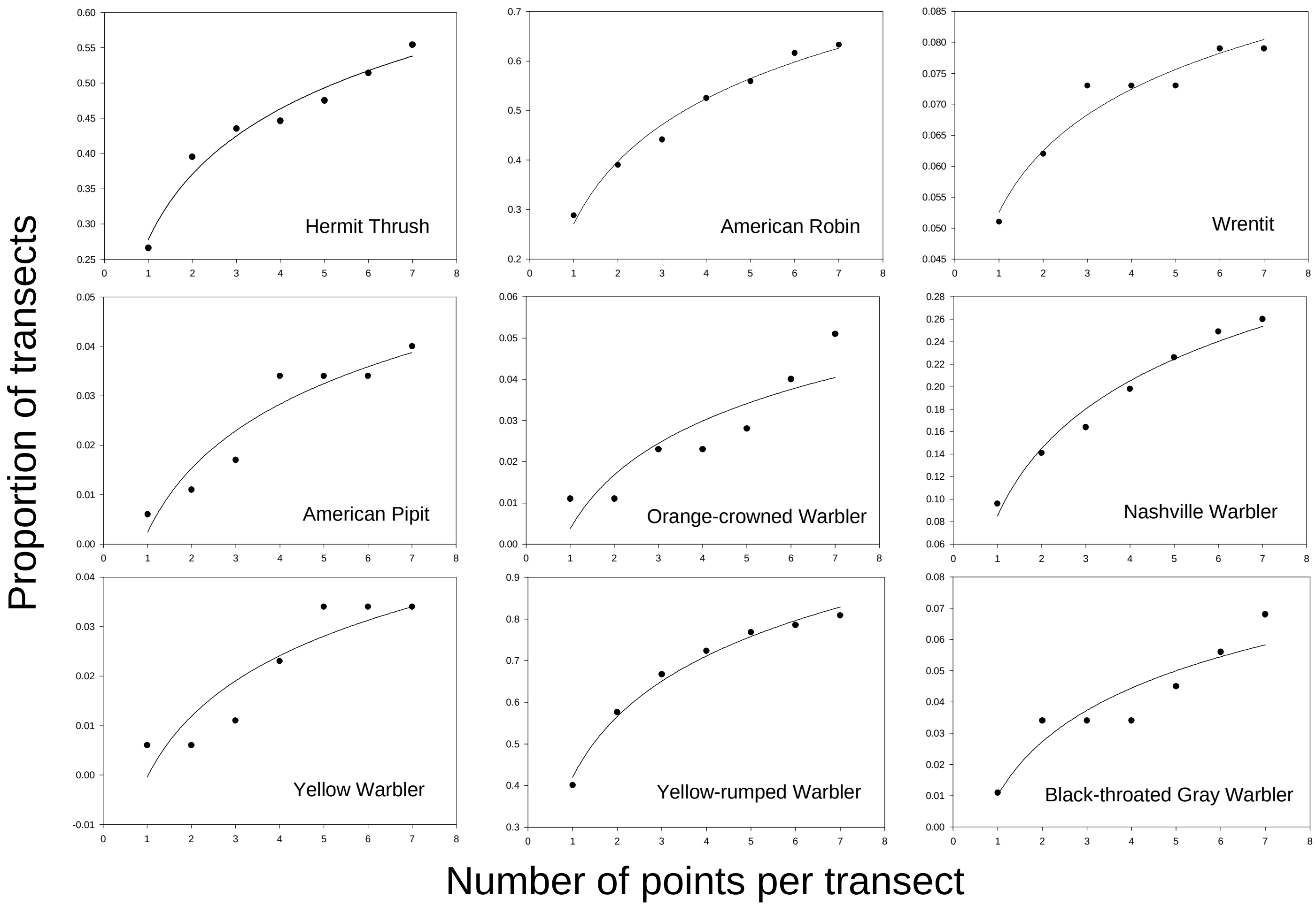


Figure 4, continued. Relationship between number of points per inventory transect and the proportion of transects on which each species was detected. Relationships are based on the first seven points of 177 SEKI inventory transects, and are modeled as logistic functions. Figure continues on next page.



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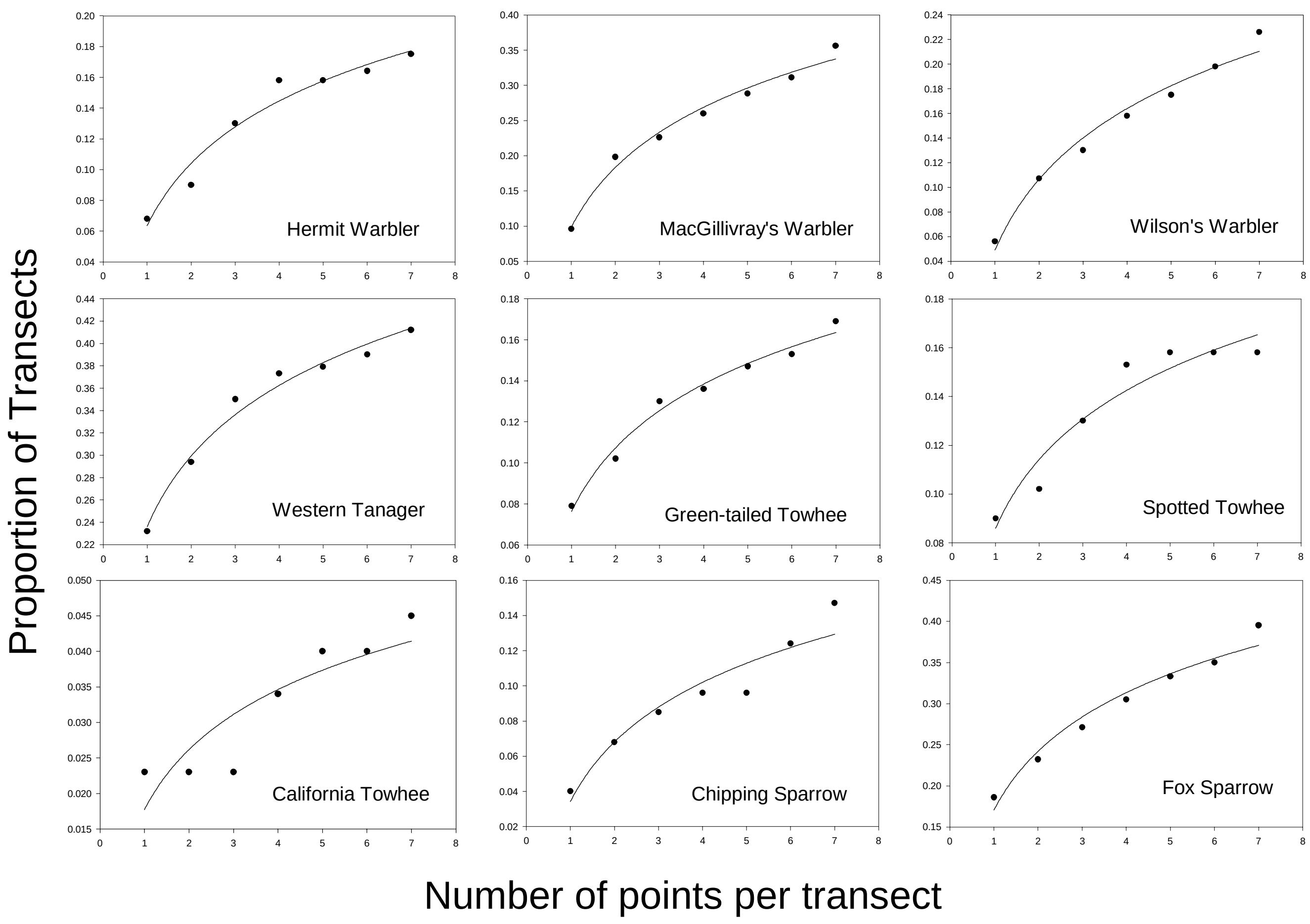

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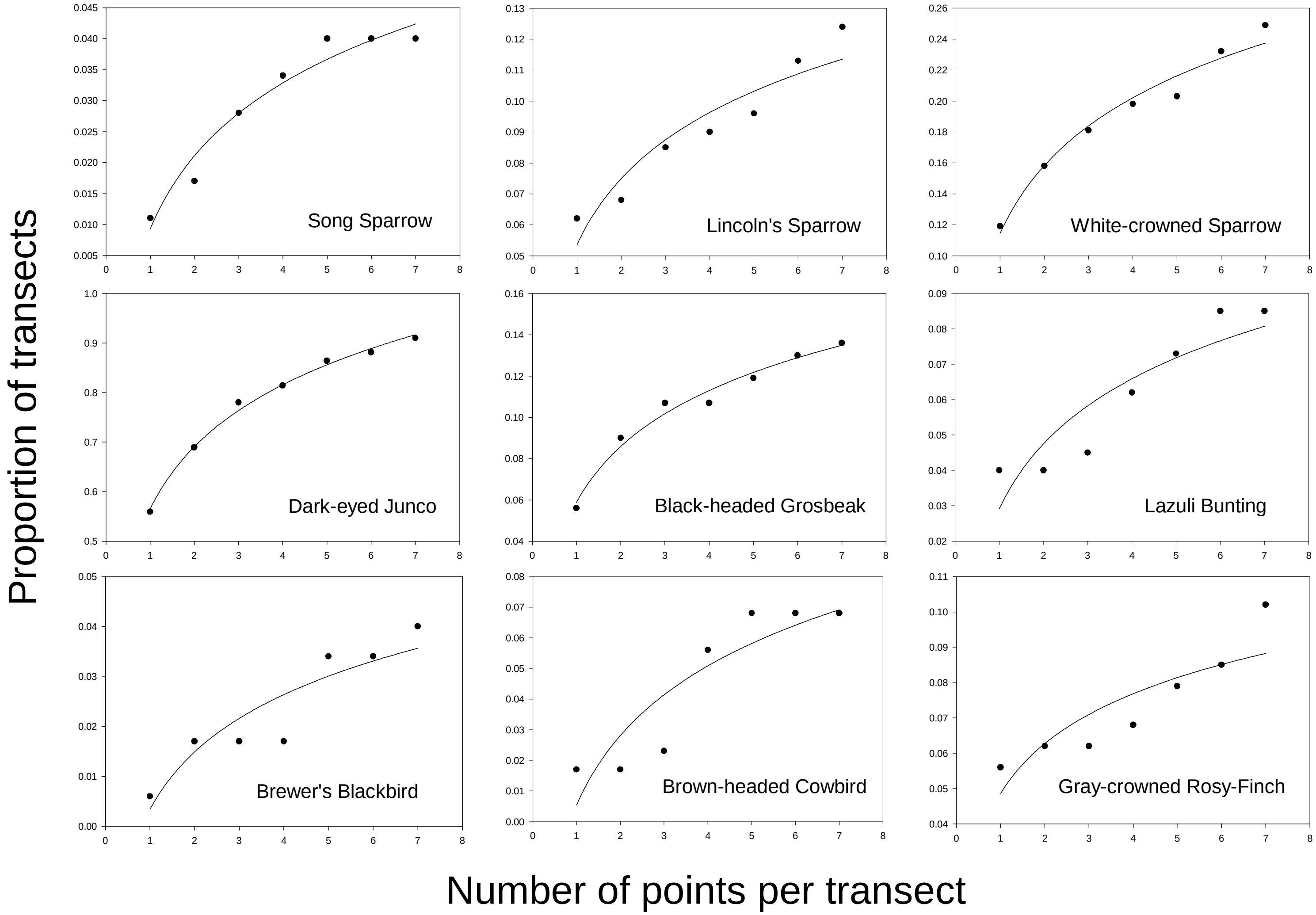

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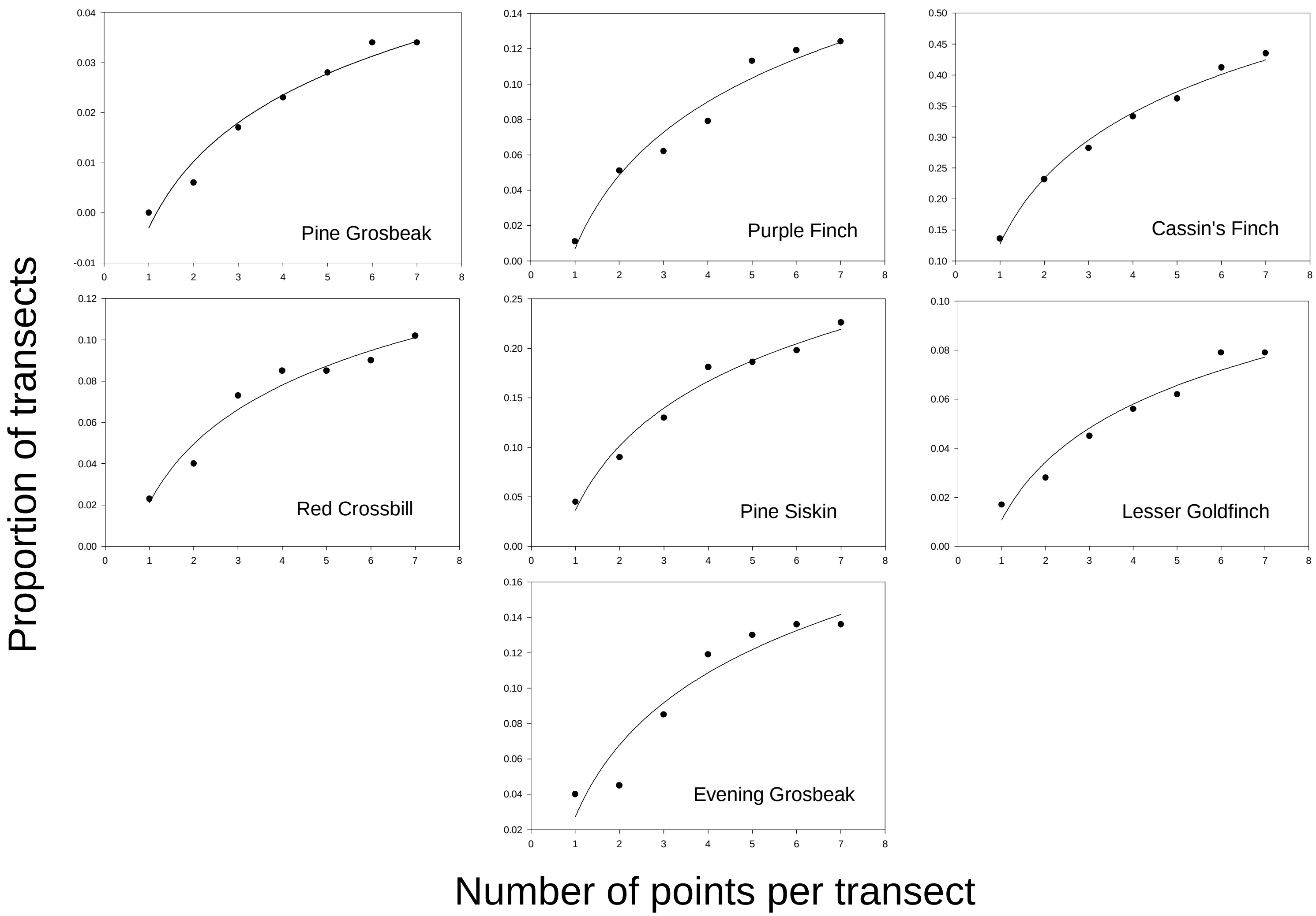

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